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Energy for Eastern South Dakota : Corn, Small Grains, Soybean and Hay Production

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ENERGY FOR EASTERN SOUTH DAKOTA

CORN, SMALL GRAINS, SOYBEAN AND HAY PRODUCTION

By

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INTRODUCTION

Problem Situation

Agriculture in the United States, an industry dependent upon energy and energy-related products, may have to make major changes as the industry is required to adjust to rising energy costs. Nationally, farmers spent 4.2 billion dollars on farm energy in 1974, Duncan et al. (1978).

South Dakota agricultural production processes consumed 3.790 x 10^{13} BTU in 1974. Invested energy, which includes energy required to manufacture fertilizers and for on-farm pumping of surface and ground water used for irrigation purposes, accounted for 21.6 percent of the 1974 total, or approximately 8.177 x 10^{12} BTU. Fertilization accounted for 18 to 19 percent of the total energy consumption, South Dakota Office of Energy Policy (1977).

Gasoline, diesel fuel, and liquid petroleum gas constitute an estimated 75 percent of the agricultural energy consumption within the state, South Dakota Office of Energy Policy (1977). Duncan et al. (1978) stated, "From 1973 through 1977, direct agricultural energy costs have risen as follows: gasoline, 69 percent; diesel fuel, 99 percent; fuel oil, 109 percent; liquid petroleum gas, 130 percent; natural gas, 220 percent and electricity, 59 percent."

Information is very limited concerning energy consumption by South Dakota agriculture. Energy and U.S. Agriculture, 1974 Data Base, (1977) published by the Federal Energy Administration and the United States Department of Agriculture is currently the primary source of energy data for South Dakota. Historical energy consumption data are not available and reliable estimates of historical consumption are difficult to obtain, South Dakota Office of Energy Policy (1977).

Agricultural production may make adjustments in its output combination, or in its consumption of various input combinations as the prices of inputs or outputs vary. Shifts in energy supplies may have effects on crop mix, production practices, location of crop production and producer net returns. Crop mix is defined as the relative number of acres of each crop produced.

The Problem

Increases in energy prices and possible physical shortages of energy and energy-related products have become recognized as imminent since the "1973 Arab Oil Embargo" occurred. South Dakota imports 95 percent of its energy needs despite the fact that it exports a large amount of electricity to other states. Furthermore, gasoline, diesel fuel and liquid petroleum gas provide an estimated 75 percent of the agricultural energy consumption within the state. Fertilization accounts for an additional 18 to 19 percent of the total energy consumed by the state's agricultural sector, South Dakota Office of Energy Policy (1977). Thus, South Dakota's agricultural economy is dependent upon the cost as well as the physical availability of energy resources.

The effects of energy shortages, caused by physical or price constraints, on South Dakota's agricultural crop mix, production practices, crop production location and net returns to producers are unknown. Two billion dollars in crops, livestock and livestock products sales annually, make agriculture the largest single industry in South Dakota's economy, South Dakota Office of Energy Policy (1977). South Dakota's decision makers may need information concerning the state's agricultural energy consumption to insure adequate energy supplies in the future. This study will attempt to obtain this information and to study various energy relationships.

An estimate of the current crop mix in eastern South Dakota will be derived. Current consumption of the four major energy sources used in the crop production process, gasoline, diesel fuel, liquid petroleum gas and electricity, will be estimated and relationships between current consumption and crop mix will be studied. Finally, the effects of energy quantity constraints and energy price constraints will be studied to determine what effects constraints may have on crop mix, total crop output levels, and net income per acre and per unit of energy consumed.

Hypotheses and Objectives

The central hypothesis of this study is that energy supplies will force the South Dakota agricultural industry to make production process adjustments.

The specific hypotheses formed to assist this study are as follows:

1) Energy consumption per acre, for crop production purposes in eastern South Dakota varies geographically. The geographical variations are caused by a variation in basic crop mix.
2) If shortages in energy occur a change in crop mix, in total crop output, and in net income per acre, and per unit of energy consumed will occur. Small grain production will replace row crop

production.

The central objective of this study is to determine what effect a change in energy availability will have on South Dakota agriculture. To evaluate the hypotheses in this study, the following specific objectives must be accomplished:

1) To estimate the total energy consumed/acre in South Dakota east of the Missouri River, in the "on-farm" production process.
2) To estimate what relationship exists between energy consumed, crop mix, crop location and number of acres of crop produced.
3) To discuss the change in crop mix, output and net income, which will occur on eastern South Dakota farms when energy quantity or price constraints are applied.

Scope and Limitations

The study is limited to the crop production processes found in eastern South Dakota. Crop classifications studied consist of 1) corn, 2) soybeans, 3) small grains and 4) hay and alfalfa. Energy sources studied consist of gasoline, diesel fuel, liquid petroleum gas electricity. Two other energy intensive inputs, fertilizers and chemicals, are also were studied.

REVIEW OF LITERATURE

American agriculture has historically provided an adequate domestic food supply and is providing an ever increasing supply of food, feed and fiber for the world. As the world population has grown many countries have found that the available agricultural resources are inadequate to provide for growing populations. Prior to World War II, several regions were net exporters of agricultural products. By 1975 a dramatic change had occurred with only three regions, North America, Australia, and New Zealand being net exporters. Approximately 1200 million tons of cereal grains were demanded by the world in 1975, with demand increasing at a rate of 25 million tons per year, Biswas et al. (1976).

The United States exported three-fourths of its wheat, more than two-thirds of its rice, one-half of its soybeans and cattle and over one-fourth of its feed grains in 1974, Kirk (1977). Total 1974 agricultural exports were valued at 21,293 million dollars, while 1974 agricultural imports totaled 9,549 million dollars. Therefore, an excess of domestic agricultural exports over supplementary imports existed in 1974 and was valued at 14,764 million dollars. Acres harvested during 1974 in the United States amounted to approximately 331 million acres, with 29 percent or 96 million acres used for producing agricultural exports, USDA (1976).

Increased crop yields have been made possible in part through increased mechanization and fertilization. The United States led the world in tractors, combines and fertilizers used in 1973, Biswas et al. (1976).

The number of acres of land economically feasible for cultivation has changed very little since 1910, but emphasis has been placed on increasing crop production per acre. The average crop yield per acre for the period 1911 to 20 as compared to the period 1967 to 76 nearly doubled, Duncan et al. (1978). Most of the increased productivity has occurred since 1940. The United States' total farm production increased 90 percent on approximately the same acreages between 1940 and 1972. Farm labor in 1972 decreased to 30.7 percent of what it was in 1940, however, mechanical power and machinery inputs increased 141 percent and fertilizer and liming materials increased 780 percent for the same period, Carter et al. (1974).

The increasing reliance of United States' agriculture on energy can be observed in the above mentioned percentages. Carter et al. (1974) gave the following reason for the increase:

1) Part of the increasing dependence is due to "relatively cheap energy supplies."
2) "Agricultural commodity programs have been capitalized into land prices and have imposed constraints on the land input that make it profitable to substitute freely fertilizer, pesticides, and machinery inputs."
3) "The social costs of waste and residue disposal and displacement of farm labor have been undervalued and not fully internalized into agricultural costs."

Pimental et al. (1973) stated, "If petroleum were the only source of energy and if we used all petroleum reserves solely to feed the world population the 66,053-billion-liter reserves would last a mere 13 years."

This assumes the world population is fed a diet high in animal protein and all energy is received only from protein sources. Pimental's study has received criticism because of the nature of the assumptions. Pimental compares energy efficiencies in corn production using only manpower in Mexico and Guatemala as compared to corn production in the United States in 1970. The relative energy efficiencies (kcal return/kcal input, this does not include energy received by the plant through solar radiation) are 10.13, 4.56 and 2.52, respectively. The 1945 energy efficiency ratio for the United States was 3.24. The lower energy efficiencies are replaced by increased efficiencies of available land, labor and capital resources.

Alternatives to mechanized agriculture, Nelson et al. (1976) were explored and the following observations made:

1) Fertilization through organic wastes and legumes is not feasible if the current levels of production are to be maintained and current soil fertility is not to be depleted.
2) Going back to draft horses is not feasible as "to operate our current 327 million acres of harvested cropland with 27 million horses and mules would require 520 x 10^{12} kcal of biological energy, more than three times the 158 x 10^{12} kcal of fossil energy used by tractors, combines and other farm machinery."
3) Farming more acres is not possible without additional land clearing, drainage, leveling, irrigation, fertilization, and conservation. These practices would require additional investments of energy and capital.
4) Alternatives to land-base agriculture have not been developed

sufficiently to supply any significant amount of food. Therefore, current alternatives to mechanized agriculture are limited.

The increased reliance of United States' agriculture on energy has occurred in farm operations, production of farm used products and in processing of farm products. Farm consumption of gasoline, diesel fuel and liquid-propane gas has changed with more emphasis being placed on diesel-powered equipment. This reflects the economy of operation which diesel-powered equipment has demonstrated. In 1964, 50 percent of the new tractors were powered by diesel. This compares to 90 percent of the new tractors in 1973, McKinsey, Jr. (1975).

Rural electric cooperatives provide much of the electricity needed for the rural community. Rural electric cooperatives have found the demand for electricity is increasing at a rate of 11 percent per year, a rate which results in a doubling of demand every 6.5 years, Partridge (1974-75).

Nitrogen in recent years has become recognized as an economically important plant nutrient in United States' agriculture. The methods of application of nitrogen to the soil has, however, changed. Relatively inexpensive energy and improved technology have resulted in shifting from nitrogen-fixing legumes to application of nitrogen in the form of commercial fertilizer. This has led to a dependence of United States' agriculture on natural gas. Ninety percent of the anhydrous ammonia produced has natural gas as a basic ingredient, McKinsey, Jr. (1975).

United States' agriculture, in 1974, used on the farm an estimated 3.699×10^9 gallons of gasoline, 2.639×10^9 gallons of diesel fuel, 3.039×10^8 gallons of fuel oil, 1.482×10^9 gallons of liquid propane gas, 1.641 x 10^{11} cubic feet of natural gas and 3.209 x 10^{10} kilowatt. hours of electricity. Approximately 88.9 percent of the total energy used by United States' agriculture for production purposes was used for crop production, Wynn (1977).

Approximately 45 percent of the total on-farm agricultural use of energy is used in farm production processes to do such things as power machinery and equipment, irrigate, heat livestock facilities and dry grain. The remaining 55 percent is used in the production of the needed farm supplies such as fertilizers, pesticides, herbicides and fungicides. The total energy used by agriculture for production purposes accounts for approximately three percent of the United States consumption of energy, McKinsey, Jr. (1975).

If the transportation of agricultural products, processing, retailing, and the many other preparatory processes which occur to the agricultural product prior to consumption are included, an additional 13 percent of the energy consumed by the United States is accounted for. Therefore the food production and processing sector accounts for approximately 16 percent of total United States' energy consumption, USDA (1977); Rogers et al. (1977).

The United States is the world's largest energy consuming country. The United States consumes eight times as much energy as the rest of the world on a per capita basis, Dvoskin et al. (1976). In 1975 the United States had five percent of the world's population and consumed 29 percent of the world's energy. The Sino-Soviet block in 1975 consumed approximately 25 percent of the world's energy with 28 percent of the world's population, Duncan et al. (1978). However, the United States produces approximately 17 percent of the world's food supply, Bashford et al. (1977).

The United States' energy productivity capabilities were sufficient to meet its demand until approximately 1950. Since 1950 the United States has grown increasingly dependent upon foreign resources. By 1960 the United States was consuming 15 percent more energy than it was capable of producing, and by 1973 the United States was importing 35 percent of its total needs, Dvoskin et al. (1976).

In 1974 gasoline was the major energy source for agricultural production, accounting for approximately 44 percent of all expenditures for energy. Although the use of diesel powered machinery is increasing, only 22.4 percent of the energy dollar was spent on diesel. Dollars spent on electricity ranked third at 19.6 percent and liquid propane gas ranked fourth at 10.6 percent. Gasoline, diesel fuel, electricity, and propane gas combined accounted for 96.7 percent of every energy dollar spent on energy for agricultural production in the United States, Rogers et al. (1977).

South Dakota has resources to provide electricity, petroleum oil, and coal, however, electricity and petroleum are the only two energy sources being derived from the state's natural resources at this time. South Dakota's production of oil amounts to approximately 450,000 barrels per year. In 1975 South Dakota produced 11.7 billion kilowatt·hours of electricity. Hydro-generating facilities produced approximately eight billion kilowatt·hours. Facilities for converting fossil fuels to steam which ultimately generates electricity, produced the remaining 3.7 billion kilowatts, South Dakota Office of Energy Policy (1977).

South Dakota's agriculture has also experienced the shift from human and animal power to mechanized agriculture, with an increasing reliance on energy and energy-related products. In 1974 South Dakota consumed 8.902×10^7 gallons of gasoline, 1.044×10^8 gallons of diesel fuel, 15,000 gallons of fuel oil, 3.133×10^7 gallons of liquid petroleum gas, 1.500×10^8 cubic feet of natural gas, 2.460×10^8 kilowatt·hours of electricity and 140 tons of coal for on-farm, agricultural production purposes. This includes all energy used for the production of crops and livestock for field operations, crop drying, irrigation, feeding, heating of facilities, automobile use for farm business and all other crop and livestock production processes.

Average price per unit of energy-related agricultural inputs paid by United States' farmers in 1977 was as follows: gasoline - 46.7¢/gallon; diesel fuel - 43.0¢/gallon; liquid petroleum gas - 36.5¢/gallon; electricity - 4.03¢/kilowatt·hour; natural gas - \$1.53/MCF; nitrogen - 18¢/pound; phosphate (P_2O_5) - 18.8¢/pound; and potash (K_2O) - 8.1¢/pound, Economics, Statistics and Cooperatives Service USDA (1978).

As prices of energy inputs increased, farmers introduced various energy-saving techniques into production operations. Minimum tillage, reduced tillage and no tillage have gradually been used to replace conventional tillage. In 1975 reduced tillage amounted to nearly 35.8 million acres, minimum tillage amounted to about 29.4 million acres and no tillage amounted to approximately 6.4 million acres. Conventional tillage still remains the most common means of tillage practices, accounting for approximately 218.2 million acres, Wynn (1977).

With reduced, minimum, and no-till tillage practices, increased use of chemicals has been required to maintain proper weed and insect control. Sources do not agree on the trade off between energy consumed in the manufacture of pesticides and the energy saved with the reduced tillage practices; however, many sources agree a net savings of energy results with reduced tillage if proper pesticide application is used, Wynn (1977). Energy savings alone have not been sufficient to encourage a large shift to reduced tillage. As reduced tillage requires better farm management and different equipment, the transition to reduced tillage by United States agriculture is slow, Dvoskin et al. (1976).

Along with changing energy costs and changes in farming practices, the energy crisis has also encouraged new research and development for agricultural energy. The National Task Force on Agricultural Energy Research and Development (1976) listed the national agricultural goals for energy research and development as follows:

1) To "insure adequate, reliable, and economic sources of energy."
2) To "produce raw materials suitable for producing energy."
3) To "achieve energy efficiency in production, processing, marketing and use of farm and forest products; in the managing of natural resources; and in the development of rural communities."
4) To "minimize adverse environmental impacts from energy use and development."
5) To "conserve energy."
6) To "substitute renewable or non-critical energy sources for petroleum and natural gas."

The Task Force stated, "If energy needs for the nation's agricultural life-sources appear in jeopardy, the agricultural research and development system must act. To act effectively the system must foresee energy needs and sources. If future shortages appear likely, the agricultural research and development system must look into the development of alternative or improved energy sources and help to rethink national energy priorities", Miller (Winter 1976-77).

The two most critical periods of fuel availability for farmers are the planting season and harvest seasons. Flexibility achieved through various tillage equipment and methods allows greater adaptability to energy shortages for the planting season than is possible for the harvest season, Lacewell (1975).

Lacewell (1975) found in a study that farmers would harvest the crops with the greatest financial net return (market value - harvest costs) first. The priority of the harvesting sequence would be based on financial net returns obtainable from the given crop. The crop yielding the smallest financial net return would be harvested last when energy supplies are insufficient.

Energy consumption for farm operations will vary between farms and between energy types. Various factors influence energy consumption. These factors include, but are not limited to, such factors as soil type, amount of moisture in the soil, depth of tillage, speed of operation, compatibility of the power source and the implement, height and thickness of stand and moisture content and maturity of the crop.

Energy consumption varies between energy sources as each source yields a different amount of energy for a given quantity, South Dakota State Planning Bureau (1976). Frith and Promersberger (1974) estimate that it takes .73 gallons of diesel fuel or 1.20 gallons of liquid propane gas to equal the power provided by one gallon of gasoline.

Irrigation accounted for approximately 23 percent of all energy consumed in crop production in 1974, Wynn (1977). Over 35 million acres were irrigated in the United States with over 69 million acre feet of water pumped from wells in 1974. Electricity provided the source of power for irrigating approximately 15.6 million acres, natural gas approximately 10.6 million acres, diesel 3.9 million acres, liquid petroleum gas 3.3 million acres and gasoline 1.5 million acres. This accounted for 19 billion kilowatt·hours of electricity, 132 billion cubic feet of natural gas, 178 million gallons of diesel fuel, 237 million gallons of liquid propane gas, and 71 million gallons of gasoline being consumed in 1974, Sloggett (1977).

Irrigation efficiency (available water to the plant ÷ total water pumped) is a function of the type of irrigation system being used. Surface irrigation efficiency varies between 30 and 70 percent, averaging approximately 60 percent. Runoff reuse system efficiency is approximately 85 percent. Sprinkler irrigation efficiencies average approximately 75 percent with a range of 60 to 90 percent, although 85 percent is the approximate efficiency of center pivot systems. Trickle irrigation efficiency range is 75 to 95 percent with an average of about 90 percent, Gilley and Watts (1977). Some factors, which affect irrigation energy consumption, are as follows: quality of water, source of water (surface or well), depth of well, type of distribution system, and motor and pump efficiencies, Commoner et al. (1974).

Irrigation in South Dakota is becoming increasingly more important. There are two basic reasons for South Dakotans to irrigate. First, irrigation reduces risk, allowing more accurate income prediction. More stable crop yields cause more stable cash flows. Second, irrigation with proper management will yield greater direct net returns, Aanderud (1970).

South Dakota projected irrigation acreage for 1976 totaled approximately 177,205 acres. Electricity was used to irrigate an estimated 110,217 acres, 62.2 percent. Diesel fuel was used to irrigate an estimated 40,114 acres, 22.6 percent. Propane accounted for an estimated 20,707 acres, 11.7 percent. Gasoline and natural gas accounted for an estimated 4019 and 1366 acres respectively, accounting for 2.3 and 0.8 percent respectively. Other sources including gravity and flowing well pressure were used to irrigate an estimated 780 acres, 0.4 percent, South Dakota Department of Natural Resource Development Division of Water Rights (1976).

Grain drying is an energy intensive operation with costs which are a function of type of grain, beginning moisture content, final moisture content, cost of energy, weather conditions and type of drying system, Wynn (1977). Four drying systems ranked from low supplemental energy inputs to high are as follows: "1) natural air drying; 2) low temperature in-bin drying; 3) medium temperature air flow in-storage-bin drying; 4) high temperature-high air flow drying", Wynn (1977).

Energy requirements increase and efficiency decreases as the speed of drying increases, Commoner et al. (1974). An estimated 12.6 bushels of corn can be dried with one gallon of liquid propane gas, removing 10 percentage points of moisture, using a combination system. This system removes five percentage points through batch or continuous flow drying, two points through dryeration and three percentage points with aeration. Using a much faster system of drying, batch or continuous flow with cooling in the dryer, an estimated 6.5 bushels of corn can be dried with one gallon of liquid propane gas, removing 10 percentage points of moisture. Various other drying speeds and techniques may yield drying efficiencies other than the above mentioned methods, Council for Agricultural Science and Technology (1975).

Farm census data for 1974 yield the breakdown of some of the major energy consuming farm equipment in South Dakota. South Dakota had 113,241 tractors, 13,941 combines (with an additional 5,386 corn heads for the combines), and 12,960 corn pickers and picker-shellers in 1974. There were 13,853 balers, 4,445 mower conditioners and 11,254 shear bar/ flywheel forage harvesters in South Dakota in 1974. South Dakota also had 23,144 self-propelled or pull-type windrowers in the state, Implement and Tractor (1977).

In 1976 there were a total of 1758 irrigation systems in South Dakota. Following is a breakdown of the type of system and total number of each type of system for 1976: gated pipe - 230; siphons - 49; center pivot - 690; hand moved sprinklers - 159; portable booms - 45; flood - 264; hydromatic - 3; jet gun - 146; towlines - 155; sidewheel roll - 16; trickle - 1. The dominant type of system is the center pivot with flood irrigation being the second most dominant, Department of Natural Resource Development Division of Water Rights (1976). Wallace G. Aanderud (1970), Economist-Farm Management, states, "Costs of production are consistently higher for the center pivot system than for most other irrigation systems because of higher fixed costs and water pumping costs." Information on the number of grain dryers within the state is unavailable.

Commercial fertilizer use in 1970 for the world was 68.1 million metric tons. Nitrogen fertilizer accounted for 31.7 million metric tons or 46.6 percent of the total. Europe used 37 percent and 30 percent of the NPK [nitrogen (N), phosphoric acid (P_2O_5), potash (K_2O)] and nitrogen, respectively for 1970. North America followed with 24 percent and 24 percent respectively, followed by the USSR with 14 and 15 percent, respectively. Asia, less Japan, accounted for 8 and 11 percent, respectively; Latin America accounted for four and four percent, respectively; Africa accounted for two and three percent, respectively and Oceania 2 and 0.5 percent, respectively. Europe, North America and USSR accounted for 75 and 69 percent of the NPK and nitrogen use respectively.

World fertilizer use is continuing to expand as the world demand for food grows. Total world use of NPK increased fourfold between 1950 and 1970. World use is expected to double again between 1970 and 1985. Nitrogen use increased sevenfold between 1950 and 1970 and is also expected to double again between 1970 and 1985.

The proportion of the world's natural gas which was used for production of nitrogen in 1970 was 8.4 percent and has been expected to rise to 12.7 percent by 1985. In the United States the natural gas used for nitrogen production was significantly lower at two percent of the total natural gas consumption of the United States.

Supplies of phosphate and potash have been limited due only to limited production facilities. Unprocessed supplies of each are abundant, University of California Food Task Force (1974).

In the United States, over 40 percent of the energy input for crop production came from fertilizer in 1974. Fertilizer was applied to 94 percent of the total corn harvested acres, 79 percent of the cotton, 66 percent of the wheat and 30 percent of the soybeans, Wynn (1977). In 1974 South Dakota used 99,100 tons of nitrogen, 74,897 tons of phosphate, and 8,436 tons of potash, Economic Research Service USDA (1976).

Pesticides are currently being used extensively in the world to protect crops and livestock. Pesticides include herbicides, insecticides, fungicides, rodenticides and others. In 1971 the United States' consumption of pesticides by cost was 41 percent of the total world's consumption. United States' consumption as a percentage of the world's consumption of herbicides, insecticides, fungicides and other pesticides was 56 percent, 26 percent, 19 percent, and 63 percent, respectively, University of California Food Task Force (1974). In 1974 South Dakota consumed 4629.5 tons of herbicide, 823 tons of insecticide and 31 tons of fungicide for agricultural purposes, Economic Research Service USDA (1976).

The Iowa Department of Agriculture and the Iowa Energy Policy Council in conjunction with the Iowa Crop and Livestock Reporting Service have in the previous few years conducted an annual survey of farmers and ranchers to determine farm and ranch energy consumption. The results of the Iowa Survey indicate a decrease in energy consumption for most of the major farm fuels in 1977. The survey included the following energy sources: diesel, gasoline, liquid petroleum gas, fuel oil, natural gas, electricity, coal and wood. All of these except diesel fuel, electricity and wood, decreased in consumption. Diesel fuel consumption increased 2.3 percent in 1977 with 158.9 million gallons used. Gasoline consumption decreased by 7.0 percent with a total of 204.2 million gallons consumed. Electricity consumption increased 2.9 percent totaling 2,536.0 million kilowatt·hours consumed. A decrease in fuel oil and natural gas of 4.7 percent and 3.0 percent, respectively was noted for 1977, with these fuels being primarily consumed in the non-farm category of home heating.

Iowa crop production consumed 127.6 million gallons of gasoline, 134.5 million gallons of diesel fuel and 67.9 million gallons of liquid petroleum gas in 1977. Crop drying in Iowa consumed 33 percent of the total energy used in crop production during 1977. Iowa farms dried, through mechanical means, 785 million bushels of corn, or 72 percent of the total corn crop. An average of 8.0 percentage points of moisture was removed, consuming 67,453,000 gallons of liquid petroleum gas and 136,818,000 kilowatts of electricity. This does not include corn dried by elevators for the elevators' own purposes.

The 1977 survey was a subsample of the 1976 sample. The survey was stratified with 22 different strata being developed. The survey used crops, hogs, cattle, sheep, hens and pullets of laying age, broilers, and turkeys for strata classifications. The total number of farms sampled was 642, of which 24 were not tabulated because the individual contacted had ceased farming. These 642 farms came from the original group of 1,009 in the 1976 survey. The survey was conducted by personal interview during the early spring of 1978, Iowa Crop and Livestock Reporting Service, Iowa Department of Agriculture (1977 and 1978).

The "Energy Consumption In Louisiana Agriculture" survey was conducted to determine the energy Louisiana's agriculture was consuming. Inquiry forms with personal interviews were used to collect data. A mail-out survey was sent to farmers and personal interviews with farmers were held to verify and complement the mail-out questionnaire. Farmers to be surveyed were provided by the county agents, except for poultry producers whose names were obtained by a poultry company in Louisiana. Information derived from personal interviews was generally more thorough and complete than the mail-out questionnaires.

"The following methods were used in analyzing information from farms producing more than one commodity:

1) A percent of the total fuel (s) that went toward each commodity was estimated by the farmer.
2) The percent of the total acreage for each commodity was determined.
3) An estimate was made on a per acre basis of how much fuel, tractor time and/or type of work each commodity required.
4) Farmers estimated the rate of coverage per tractor/harvester operation and number of trips over the field.
5) Energy requirements for multiple commodity farms were compared to farms producing single commodities.
6) Farmers were recontacted for additional information or clarification of information reported.

After the information from each farm was evaluated, the data were filed according to commodity type. Analysis of each commodity was collectively made by combining the different farm samples," Nolen et al. (1976).

Kansas and Nebraska received joint funding from the Federal Energy

Administration to: 1) develop a limited, trial, voluntary statewide energy conservation program for on-farm production agriculture; and 2) conduct a fuel use survey on a limited number of farms in the two states. The survey in Nebraska was conducted with the assistance of the Cooperative Extension Service and 108 farmers and ranchers. Fuel meters were installed on the farmers' fuel tanks and energy use handbooks were given to the individual farmers for the purpose of maintaining fuel use records for various operations.

Farmers from 30 counties were chosen by the individual county agents from those counties to assist in the survey. A degree of reluctance was noted as farmers were afraid the program was associated with fuel allocation. The Nebraska test determined that an energy management program is practical and profitable, Bashford et al. (1977).

Crop production has played a vital role in South Dakota's economy and in South Dakota's agriculture. Some of the major crops grown in South Dakota consist of: corn, wheat, soybeans, oats, barley, rye, flax, sorghum, sunflowers, potatoes, hay and alfalfa.

In 1975 South Dakota ranked second in rye and flaxseed production, third in durum wheat, twelfth in all wheat, second in oats, sixteenth in corn, seventh in barley, sixth in both alfalfa seed and hay, twenty-second in soybeans, and thirty-second in potato production, South Dakota Crop and Livestock Reporting Service (1975).

In 1975 South Dakota produced 83,250,000 bushels of corn and 5,760,000 tons of corn silage; 63,294,000 bushels of wheat; 98,120,000 bushels of oats; 17,670,000 bushels of barley; 2,346,000 bushels of rye; 4,176,000 bushels of flaxseed and 8,425,000 bushels of soybeans.

South Dakota also produced 6,162,000 bushels of grain sorghum and 262,000 tons of sorghum silage in 1975, South Dakota Crop and Livestock Reporting Service (1975).

Estimated energy consumption for 1975 South Dakota agriculture is unavailable. However, the Economic Research Service, USDA has estimates of fuel consumption by fuel type during 1974 for all states, Economic Research Service USDA, (1976).

THEORY

South Dakota agriculture periodically must make adjustments to changes in prices of outputs and/or prices of inputs. As the price of an input varies, a profit-maximizing entrepreneur will employ units of a variable productive service until the point is reached at which the value of the marginal product (VMP) of the input is exactly equal to the input price P_X.

Therefore, given the market price or the supply curve of the input to the firm, a perfectly competitive producer determines the quantity of the input to utilize by equating the value of the marginal product of the input to the price of the input. Therefore, the value of the marginal product curve is established as the firm's demand curve for the input X, when only X is variable.

As the price of the input X changes (ΔP_X), the change in the value of the marginal product ($\Delta P_B MP_X$) must equal (ΔP_X) if the same level of X is to be employed. If the MP_X is fixed, then the price of the output B (P_B) must increase (which must be caused by a shift in the demand for

$$P_B MP_X = P_X$$

$$(P_B + \Delta P_B) MP_X = P_X + \Delta P_X$$

$$MP_X P_B + \Delta P_B MP_X = P_X + \Delta P_X$$

$$\Delta P_B MP_X = \Delta P_X$$

$$\Delta P_B = \Delta P_X \cdot \frac{1}{MP_X}$$

B) in an equal proportion to P_X if the same level of production is to be maintained, ceterus paribus.

Where substitution of inputs or outputs can occur, various combinations are possible. At profit maximizing equilibrium $P_B = \frac{P_X}{MP_X} = \frac{P_Y}{MP_Y} \cdots$, if the P_X increases then the $\frac{P_X}{MP_X} > \frac{P_Y}{MP_Y} = P_B$. Therefore the quantity of X consumed decreases causing the marginal product of X to increase. This causes the ratio $\frac{P_X}{MP_X}$ to decrease, so $\frac{P_X}{MP_X}$ again approaches $\frac{P_Y}{MP_Y} = P_B$. However, as a change in X occurs, a change in the MP_Y occurs. If X and Y are substitutes, $(+)\Delta X$ yields $(-)\Delta MP_Y$ if X and Y are complements, $(+)\Delta X$ yields $(+)\Delta MP_Y$.

Therefore, when one input replaces another input the combinations which occur will depend upon the relationship between the inputs. If the $P_B\uparrow$ and the price of all inputs remain constant, no substitution between inputs will occur. However, a substitution between outputs will occur, with more inputs being directed toward the production of B. This substitution will occur until $VMP_{X/B} = VMP_{X/A}$, where $VMP_{X/A}$ = the value of the marginal product of X in producing all other outputs.

To determine the proper input mix a producer must be aware of relative input prices to minimize the cost of producing a given output or maximize output for a given level of cost. Considering the variable input being studied as X, and all other variable inputs as Y, the market input price ratio $\frac{P_X}{P_Y}$ tells the producer the rate at which he can substitute one input for another (or group of other inputs) in purchasing inputs. The relative MP of each input X and Y must be recognized to minimize the cost of producing a given output or maximize output for a given level of cost. The marginal rate of technical substitution is the ratio of the marginal products ($MRTS_{X \text{ for } Y} = \frac{MP_Y}{MP_X}$). The MRTS tells the producer the rate at which substitution in production can occur. To minimize cost subject to a given level of output and input prices, therefore, the producer must purchase inputs in quantities such that the MRTS of X for Y is equal to the input price ratio (the price of Y to the price of X). Inputs should be employed therefore in the proportion which ensures $\frac{MP_Y}{MP_X} = \frac{P_Y}{P_X}$.

When more than one output can be produced from a given input the rate of product transformation (RPT) must be discussed. The rate of product transformation is the rate at which output A must be sacrificed to obtain more B, or vice versa, without varying the input of X. The RPT equals the ratio of the marginal cost of A(MC_A) to the marginal cost of B(MC_B) in terms of X, at a given combination of A and B. The RPT also equals the ratio of the MP_X in producing A to the MP_X in producing B.

$$RPT = -\frac{\Delta A}{\Delta B} = \frac{MP_{X/A}}{MP_{X/B}} = \frac{MC_A}{MC_B} \qquad MC_A,\ MC_B,\ MP_{X/A},\ MP_{X/B} > 0$$

South Dakota agricultural producers may make adjustments in output or input combinations as the prices of inputs or outputs vary. The adjustments which may be expected when one of those inputs (energy) varies is discussed in this paper. How this output combination changes in response to various output price levels is also discussed in this paper.

The demand for energy is a derived demand and is a function of output $f(Q_{output})$. Therefore, the demand for energy depends on the level of production, the substitution possibilities available from the various inputs given the production technology, and the relative prices of the inputs. Therefore, if the possibilities of substitution between energy and non energy inputs is limited and difficult, industries may be expected to shift to non energy intensive outputs as energy input prices increase and a change in the technology of the industry may also occur, Brendt and Wood, (1975).

Brendt and Wood found for manufacturing type industries the following: 1) the demand for energy is inelastic; 2) energy and labor are slightly substitutable; 3) energy and capital are complementary factors, and 4) capital and labor are substitutable. These results imply that if energy prices rise relative to other factor prices, production processes will be altered to become more labor intensive and less energy and capital intensive. To the extent that manufacturing and agricultural production are comparable, similar results may be expected for agriculture.

Various studies, using linear programing and input-output analysis, have analyzed the effects of changes in energy prices. The University of Missouri-Columbia examined potential adjustments which Midwest grain farms might make as higher energy prices occur. The study estimated changes in specific enterprises and changes in production practices which would occur as energy prices changed from zero (free energy) to five times 1975 prices. Output prices used were the following: corn - \$2.15/bushel; soybeans - \$4.75/bushel, and wheat - \$3.00/bushel.

The study revealed at higher energy prices, acreage substitution occurs first from corn and double cropped soybeans-wheat to single crop soybeans, then to single crop wheat. Corn, a large user of energy, is suited best for low energy prices. Soybeans, which uses relatively less energy than corn, competed better at higher energy prices. However, wheat, a low energy demanding crop, relative to corn and soybeans, displaced both corn and soybeans at high energy prices.

The study also revealed fertilization rates, particularly for corn, varied substantially. At relatively low energy prices fertilization of corn with commercial fertilizers was relatively heavy. At high energy prices all fertilization was organic, coming from a cattle feeding program incorporated in the linear program.

The change of tillage practices in response to the effect of higher energy prices on the price of chemicals was noticeable. A no-tillage system which uses relatively large quantities of chemicals was used only when energy prices were low. At higher energy prices a switch was made to minimum tillage (15-inch rows), and at still higher energy prices mechanical weed control was substituted for chemical weed control. Fuel consumption was found to be very inelastic with respect to price and chemical consumption was less inelastic, Kliebenstein and Chavas (1977).

A study conducted at Michigan State University examined the effect of increased energy prices on corn and soybean production in south-eastern Michigan. The study examined the effects of increased crude oil prices and natural gas prices as corn and soybean prices remained constant at $2.25/bushel and $4.50/bushel respectively. The study examined natural gas decontrol, crude oil decontrol, and natural gas and crude oil decontrol combined.

The results of the study indicated that natural gas prices would have to double before a significant change in corn acreage would occur. The effect of price increases of crude oil on corn acreage were also insignificant. The effects of increased prices of crude oil and natural gas prices individually did, however, reduce net profits.

As both natural gas prices and crude oil prices increased simultaneously, a slow rate of substitution occurred from corn to soybeans at corn prices of $2.25/bushel and soybean prices less than $5.00/bushel. At soybean prices higher than $5.00/bushel, substantially larger decreases in corn acreage occurs as energy prices increases.

Liquid propane gas and nitrogen use declined with either changes in the soybean-corn price ratio, or in the absolute prices of crude oil and natural gas. Changes in the soybean-corn price ratio had a substantially greater effect than a change in the absolute prices of crude oil and natural gas, Lehrmann, Black, and Connor (1976).

The impact of increased energy costs on the location of crop production in the corn belt was studied by Swanson and Taylor (1977). The study used linear programing to investigate the impacts. The crops competed for land in each land control unit and the model sought those combinations of crops and practices that would maximize returns to land. The higher prices of energy-related inputs changed the basis on which the competition occurred. The study found in three land resource areas small grains gained in comparative advantage against corn and soybeans. These areas represent the western edge of the corn belt in Nebraska, the Dakotas, and the clay pan area of Illinois.

The energy-intensiveness of a crop is substantially increased when a crop is irrigated. The effect of increased energy prices, specifically natural gas, on irrigated crops in the Oklahoma Panhandle was studied by Mapp and Dobbins, (1976). Rising natural gas prices increase the cost of pumping irrigated water and, ceteris paribus, reduce the level of net returns associated with irrigated crop production. The study found a shift from irrigated crop production to dryland crop production occurred as energy prices increased. About a two-thirds reduction in net returns accompanied rising natural gas prices and the return to dryland production.

Although relatively little natural gas is used for irrigation in South Dakota (0.9 percent of the total South Dakota irrigated acreage) various fossil fuels were the direct energy source for 40.1 percent of the irrigation which occurred in 1976. Electricity was the major energy source for 55.2 percent of the irrigation in 1976, South Dakota Department of Natural Resource Development, Division of Water Rights (1976). As the price of these energy sources increase, similar results may be expected for South Dakota irrigation.

As relative commodity prices change, shifts in crop production occur as well as shifts in energy consumption. Lehrmann, Black and Connor (1976) also studied the change in relative prices of corn and soybeans. The study indicated the acreage in corn varies from 3 to 100 percent as soybean price changes with corn price held constant. The soybean-corn price ratio had to be greater than 1.9:1 before soybeans entered the solution. Corn acreage decreased at an increasing rate as soybean prices increased. Total energy consumption declines as soybean prices increased due to the shift in crop mix.

Finally, the effect of increased energy costs or reduced energy supplies on commodity prices and the consumer must be discussed. Dvoskin and Heady (1977) used an interregional linear programing model to analyze changes in agricultural production under various energy situations. The alternatives evaluated were the following: "A) a base run, B) the minimization of total energy used in crop production subject to point demands specified for agricultural commodities, C) an energy shortage in the agricultural sector, D) higher energy prices, and E) a combination of high exports and high energy prices."

The model yielded different effects on commodity prices between an energy reduction and a high energy price. A 10 percent national energy reduction for agricultural production caused a sharp increase in commodity prices. Doubling energy prices had a much smaller increase in commodity prices, due largely to the very inelastic demand for energy. Doubling energy prices caused only a five percent reduction in total energy consumed for agriculture.

The 10 percent energy reduction alternative resulted in a 41 percent reduction in irrigated acres. The doubling of energy prices caused a 22 percent reduction in irrigated acres. Under high exports irrigated acres increased even when energy prices doubled. Energy used for irrigation generally increases in proportion to increases in yield.

Increased energy costs or reduced energy supplies, according to the study, are likely to reduce irrigated acres and nitrogen applications. This would result in reduced crop yields and total agricultural production. Lower agricultural production would increase commodity prices, and because of the inelastic demand for agricultural products, it would probably result in an increase in net farm income, Heady and Dvoskin (1977).

Adams, King, and Johnston (1977) studied the effects on consumers' and producers' surplus under four conditions for California grain crop and vegetable crop production. The conditions studied consisted of the following: A) the effect of statewide versus regionally mandated energy allotments; B) the effect of increased energy costs; C) the effect of reduction in nitrogen supply; D) the effect of a reduction of both nitrogen and fuel supplies.

A regional restraint yielded equal absolute decreases in consumers' and producers' surpluses. Increased energy costs showed producers' surplus decreased more than consumers' surplus. When absolute reductions in fertilizer supplies occurred producers' surplus was reduced and consumers' surplus remained constant. When fuel supplies and nitrogen supplies were reduced simultaneously, producers' surplus remained the same and consumers' surplus dropped sharply.

The study showed from a policy standpoint, the impact of combined energy reductions and high fuel costs suggests that subsidization of energy in some cases may be of more benefit to consumers than producers. This is as would be expected if the demand for the agricultural commodity under consideration is inelastic and the supply of the commodity is elastic.

All of the studies concluded that as the price of energy increased a substitution to less energy intensive crops occurred. Irrigated cropping practices are replaced by dryland cropping practices. As this crop substitution takes place, labor is substituted for capital as demonstrated by the reduction of irrigation and a shift to dryland crop production. Labor and land become substitutes for chemicals and fertilizers. The complementarity of energy and capital is demonstrated by the reduction in irrigated acres and reduced tillage as energy prices increase.

The demand for energy in agriculture is a derived demand and is a function of output. Energy and labor as well as capital and labor are substitutes. Energy and capital are complements. Commodity prices increase more rapidly when energy supplies face physical constraints than when price constraints are faced. Relative prices of commodities produced affect energy consumption. As the price of less energy intensive crops increases energy consumption decreases. Finally, consumers' and producers' surplus are affected differently for various energy availability situations. The elasticity of the energy supply and demand functions will influence future crop mix and production practices as well as commodity prices.

RESEARCH METHODS AND PROCEDURES

The following research procedural guidelines were established and followed to obtain the necessary information for the research project and to properly evaluate the information after it was obtained. The eastern part of the state of South Dakota was stratified according to the five USDA Crop and Livestock Reporting Service districts in eastern South Dakota (Figure 1). Two counties for each district, considered representative of that district by extension specialists, as to production practices, crop mix, yields, and general geographic location, were chosen from which a random sample of farmers was drawn. Names of rural inhabitants were obtained from the county agents of the respective sampled counties. The lists of names received were obtained from the county rural directories. A questionnaire and letter explaining the questionnaire (Appendix A) were sent out to 1500 (approximately five percent of the eastern South Dakota farm population) different addresses with a proportion being sent to each county, based on the county's contribution to the total populace of the counties surveyed.

Each letter of the first mailing of the questionnaire was sent under the classification of "address correction requested" to allow for incorrect addresses. The first mailing occurred during the last half of October, 1978. In the last half of November a mailing of approximately 280 questionnaires was sent out to alternate names to correct for incorrect addresses and non-farm inhabitants, and in the last half of December a second mailing occurred which was sent to all addresses which had not replied. This consisted of mailing approximately

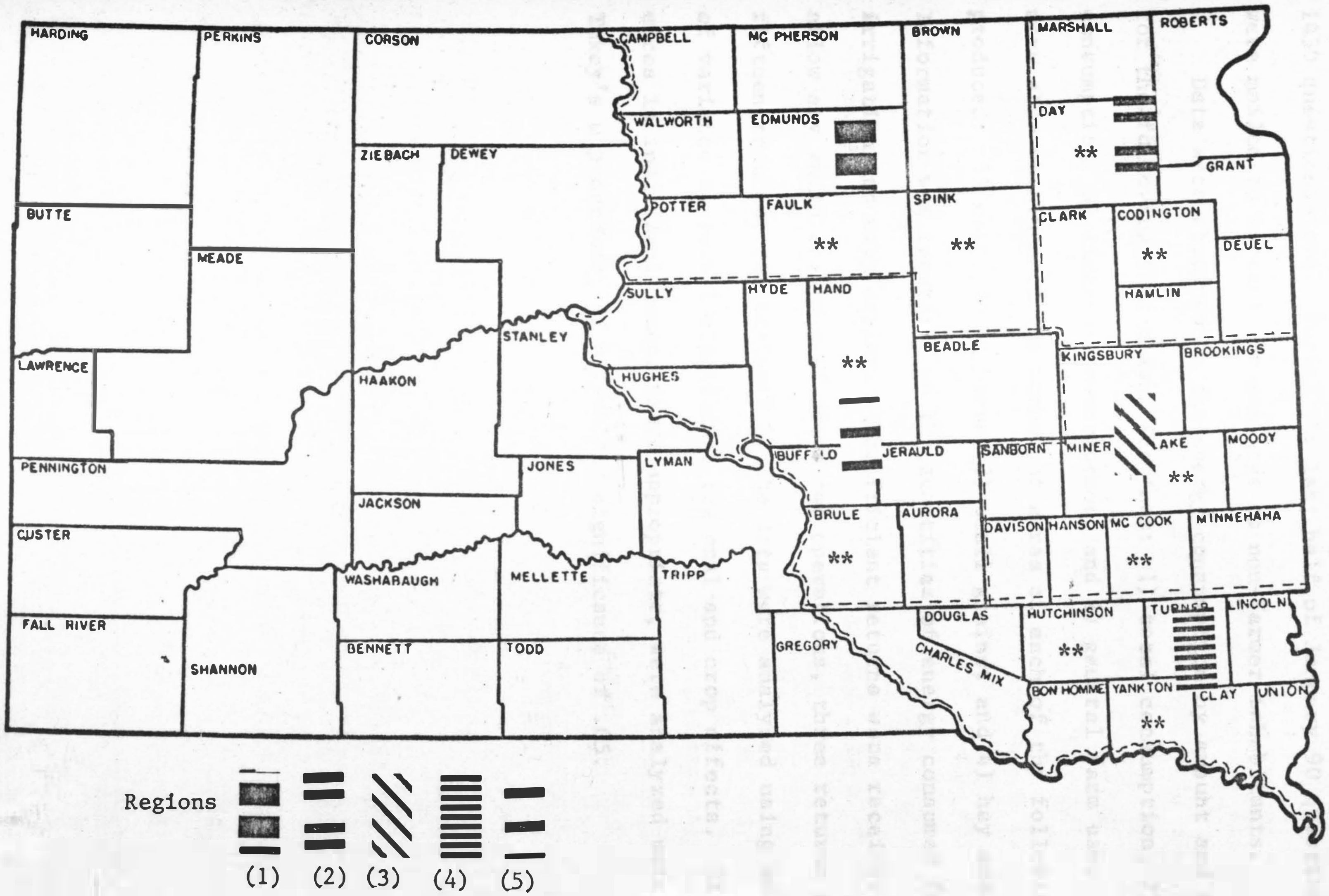

Figure 1. Eastern South Dakota Crop Production Energy Consumption Survey Districts and Surveyed Counties (1978).
** Indicates Counties Surveyed

1430 questionnaires. During the last half of January 90 questionnaires were mailed to correct for mailings to non-farmer inhabitants.

Data were obtained on the energy consumption by amount and type for the following four classifications: 1) total consumption, 2) crop consumption, 3) livestock consumption, and 4) general farm use. Data were also obtained on the number of acres of each of the following crops produced: 1) corn, 2) soybeans, 3) small grains, and 4) hay and alfalfa. Information was requested on the quantities of energy consumed for irrigation and crop drying. (Insufficient returns were received to allow any valid analysis of these two operations, three returns and fifteen returns, respectively.) The data were analyzed using analyses of variance to reveal significant regional and crop effects. Differences in individual means, where appropriate, were analyzed using Tukey's ω procedure, at a level of significance of .05.

RESULTS AND DISCUSSION

The results of this investigation are based upon the analyses of the information provided in the returned questionnaires and the micro economic theories of substitution and production. Of the 1500 questionnaires mailed out, a total of 136 usable responses, 9.1 percent, were received. The number of questionnaires mailed, the number of usable responses and the percentage of responses for each of the five regions indicate a fairly uniform response except for region 5, Table 1. No explanation can be provided for the lower response rate of region 5. A resistance to answer the questionnaire was noted for all regions. Sixty-eight questionnaires were returned with an indication of refusal to answer or refusal to complete all sections of the questionnaire.

Table 1. Regional Response Rate to the Eastern South Dakota Energy Consumption Survey, (1978).

Region	Questionnaires Mailed	Completed Questionnaires	Percentage Response
1	231	23	10.0
2	292	33	11.3
3	338	32	10.6
4	402	38	10.6
5	237	10	4.2
Total	1500	136	9.1

The validity of the statistical analysis and the accuracy of results are limited due to the small response to mail out ratio. The probability of sample bias is increased as the total number of sample returns relative to total sample size is low. Irrigation and crop drying will not be discussed in detail as insufficient responses were received regarding these two operations. Irrigator returns were not included in the analyses. Observations which included crop drying were analyzed, however, crop drying was not analyzed separately. Data on crop production will be reported on the basis of only those respondents producing that crop unless otherwise specified.

Statistical Analysis

The mean farm size of returned questionnaires was 499.7 acres with a standard deviation of 422.1 acres. The largest farm sampled was 3420 acres, and the smallest farm was 60 acres. The range in farm sizes therefore was 3360 acres. Surveyed farms contained a total of 67,964 acres.

Corn comprised 15,605 acres (24.0 percent) of the total acres reported in the survey. The number of acres of corn produced ranged from 10 acres to 840 acres with a mean of 131.1 acres/farm and a standard deviation of 113.5 acres. Soybeans comprised 1644 acres (2.4 percent) of the total acres reported. Twenty-four respondents reported raising soybeans with a range from 10 acres/respondent to 300 acres/respondent. The mean number of acres of soybeans produced was 68.5 acres with a standard deviation of 65.0 acres. Small grains accounted for 36,273 acres of the total (53.4 percent). There were 126 farms which reported raising small grains. The number of acres of small grains produced ranged between 20 acres/respondent to

2800 acres/respondent. The mean number of acres of small grains produced was 287.9 acres with a standard deviation of 342.0 acres. Hay and alfalfa comprised 14,442 acres of the total surveyed (21.2 percent). One hundred seventeen farms produced hay or alfalfa. Acres of hay or alfalfa produced ranged between 2 acres/observation and 1100 acres/ observation. The mean number of acres of hay and alfalfa produced by all hay and alfalfa producers was 123.4 acres with a standard deviation of 176.0 acres.

Data collected by regions are listed in Appendix B. A summary of the statistical analyses of the survey returns is given in Appendix Tables C_1 through I. Figures 2 through 13 supplement the statistical analyses. Regional influences on type of crop being produced were analyzed. Appendix Tables C_1 through C_4 summarize the analyses of variance for eastern South Dakota crop production by region. The dependent variables being considered are the number of acres of a given crop being produced per observation. Statistical comparisons of mean corn acres/observation are summarized in Table 2.

Table 2. Mean Corn Acres/Observation By Region (1978).

$\omega_{.05}$ (5, 131)					
Region	2	1	5	4	3
Acres	43.97	84.52	135.50	149.89	161.22

Region R(2) was significantly different from R(4) and R(3) with R(2) indicating the lowest mean corn acres/observation at 43.9 acres. Region R(3) had the largest mean corn acres/observation at

161.2 acres. Region R(4) indicated the second largest mean corn acres/observation at 149.8 acres. There were no significant differences between R(2), R(1) and R(5). There also were no significant differences between R(1), R(5), R(4) and R(3). The aggregate mean was 114.7 acres.

Statistical comparisons of mean soybean acres/observation are summarized in Table 3.

Table 3. Mean Soybean Acres/Observation By Region (1978).

$\omega_{.05}$ (5, 131)

Region	2	5	3	1	4
Acres	0.00	0.00	11.38	13.04	25.79

Region R(4) was significantly different from R(2) and R(5) with R(4) indicating the largest mean soybean acres/observation of 25.79 acres. Regions R(2) and R(5) both produced no soybeans. Regions R(2), R(5), R(3), and R(1) were not significantly different from each other. Regions R(3), R(1) and R(4) were also not significantly different from each other. Attention must be given to the fact that there were only 27 observations which raised soybeans, therefore the probability of a biased sample is increased. Region R(1) had only one observation raising soybeans. The observation indicated it produced 300 acres of soybeans. Region R(3) had six observations and R(4) had 17 observations reporting soybean production. The aggregate mean was 12.1 acres.

Statistical comparisons of the mean small grain acres/observation by region are summarized in Table 4.

Table 4. Mean Small Grain Acres/Observation By Region (1978).

$\omega_{.05}$ (5, 131)					
Region	4	3	2	1	5
Acres	92.58	128.94	392.82	455.22	519.60

Regions R(4) and R(3) were significantly different from R(2), R(1) and R(5). Regions R(4) and R(3) indicated the least average acreage of small grains/observation at 92.5 acres and 128.9 acres respectively. Regions R(2), R(1) and R(5) produced the greatest acreage of small grains at 392.82 acres, 455.22 acres and 519.60 acres respectively. There was no significant difference between R(4) and R(3). There also were no significant differences between R(2), R(1) and R(5). The aggregate mean was 266.7 acres.

Statistical comparisons of mean hay and alfalfa acres/observation are summarized in Table 5.

Table 5. Mean Hay and Alfalfa Acres/Observation By Region (1978).

$\omega_{.05}$ (5, 131)					
Region	3	4	2	1	5
Acres	42.50	65.29	91.73	151.78	408.20

Region (5) was significantly different from all other regions, indicating the greatest mean acreage of hay/observation. Region R(3) was significantly different from R(1) with R(3) indicating the lowest mean acreage/observation and R(1) the second highest mean acreage/observation at

42.50 acres and 151.78 acres, respectively. Regions R(3), R(4) and R(2) were not significantly different from each other. Regions R(4), R(2) and R(1) also were not significantly different from each other.

Figure 2 illustrates the mean number of acres of each crop being produced by region. Figure 3 illustrates the proportion of crop acres (crop mix) in corn, soybeans, small grains, and hay by region. Regions R(3) and R(4) produced the highest proportion of corn, approximately 47 percent and 45 percent of the total crop mix for the two regions. Regions R(1), R(2) and R(5) produced the largest proportion of small grains, approximately 65 percent, 74 percent and 49 percent respectively. Region R(5) produced the highest proportion of hay, which accounted for approximately 38 percent of the crop mix in R(5). Region R(4) produced the greatest proportion of soybeans which accounted for approximately 8 percent of the crop mix in R(4). Regions R(2) and R(5) produced no soybeans. Corn accounted for 19.4 percent of the total crop acreage and small grains accounted for 53.5 percent of the total crop acreage in the surveyed territory during 1978.

The determination of basic crop mix for a given farm operation is dependent upon several factors. These factors include but are not limited to the following:

1. The maximum expected financial return/acre, which is a function of the price of the crop, average expected yields and input costs, is a primary determining factor of crop mix. Weather, soil conditions and fertility are major factors in determination of expected yield. Fertilizers, chemicals and fuel costs are major factors in determining input costs.

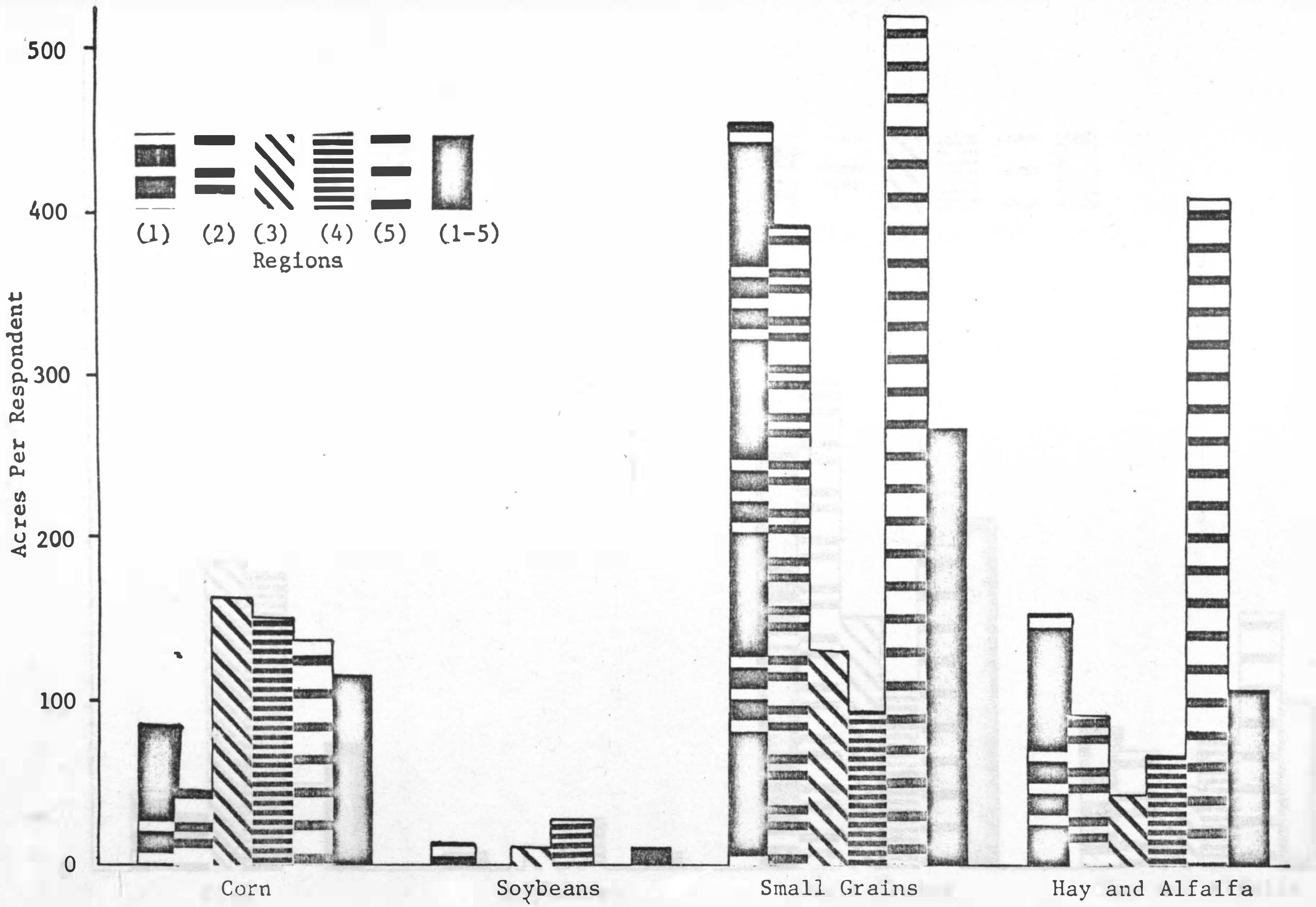

Figure 2. Average Number of Acres/Respondent of Each Crop Type for Eastern South Dakota Crop Production By Region, (1978).

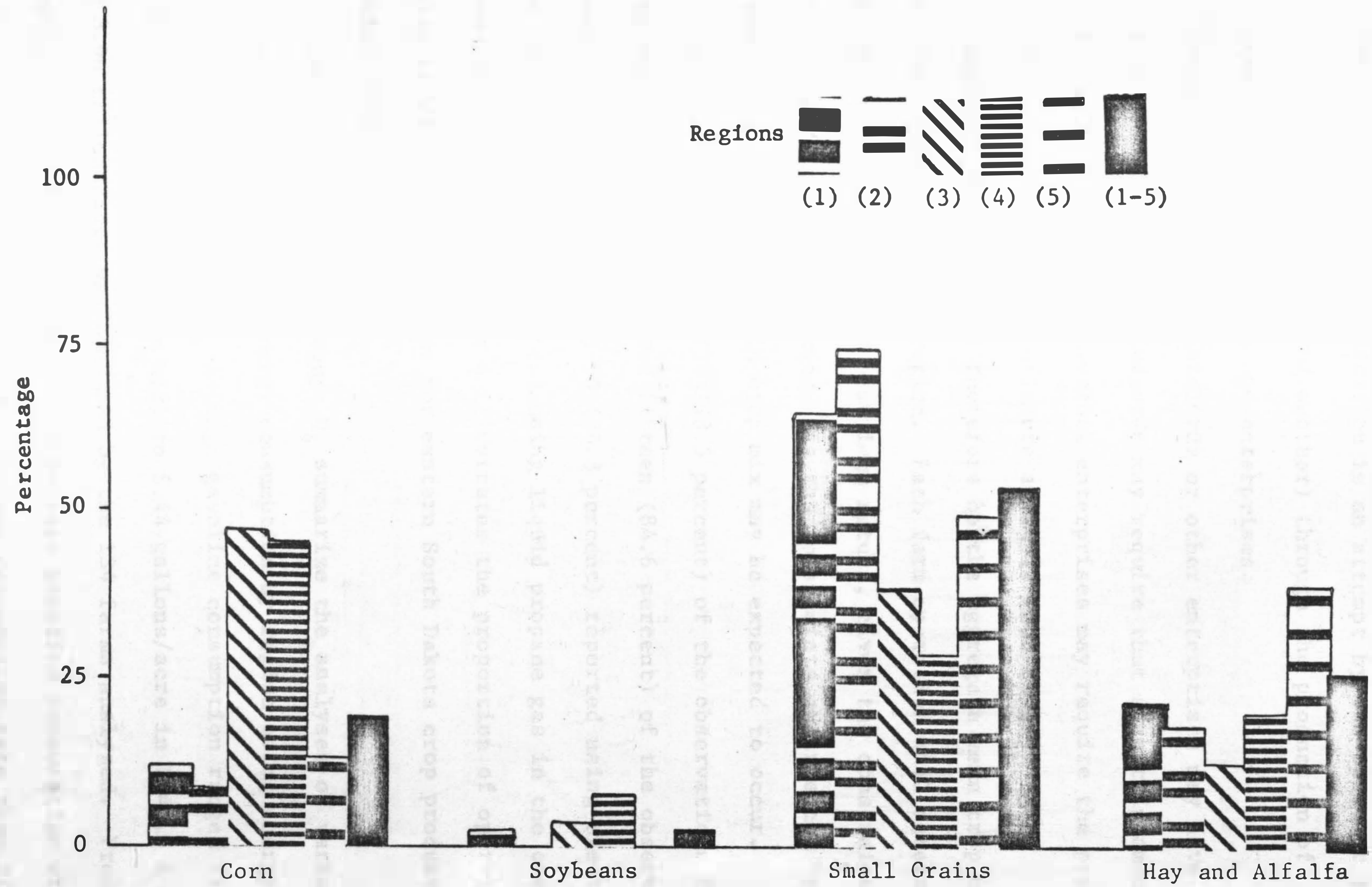

Figure 3. Percentage of Crop In Corn, Soybeans, Small Grains, and Hay and Alfalfa In Eastern South Dakota By Region, (1978).

2. The desire for diversification is an attempt by the operator to eliminate risk (price and weather) through the production of several different crops and enterprises.
3. Constraints formed by landlords or other enterprises may have an effect on crop mix. Landlords may require that a certain amount of a crop be produced. Livestock enterprises may require the production of certain crops to insure an ample feed supply.

Regional crop mix will therefore be the aggregate mean crop mix of each farm operation for a region. Each farm operation will determine the crop mix which offers the maximum return, given the constraints placed upon the farm operation. As the constraints experienced by producers change, changes in crop mix may be expected to occur.

Gasoline was used by 134 (98.5 percent) of the observations for crop production. One hundred fifteen (84.6 percent) of the observations reported using diesel fuel; 50 (36.8 percent) reported using electricity and 26 (19.1 percent) reported using liquid propane gas in the crop production process. Figure 4 illustrates the proportion of operations using various energy sources for eastern South Dakota crop production during 1978, by regions.

Appendix Tables D_1 through D_4 summarize the analyses of variance for eastern South Dakota energy consumption by region using energy type as the dependent variable. Average gasoline consumption ranged from 3.30 gallons/acre in Region R(2) to 5.44 gallons/acre in R(4). A mean of 3.96 gallons/acre was consumed by the 134 farms analyzed. Production region had a significant effect on average gasoline consumption with Region R(4) having a significantly higher consumption rate than R(2),

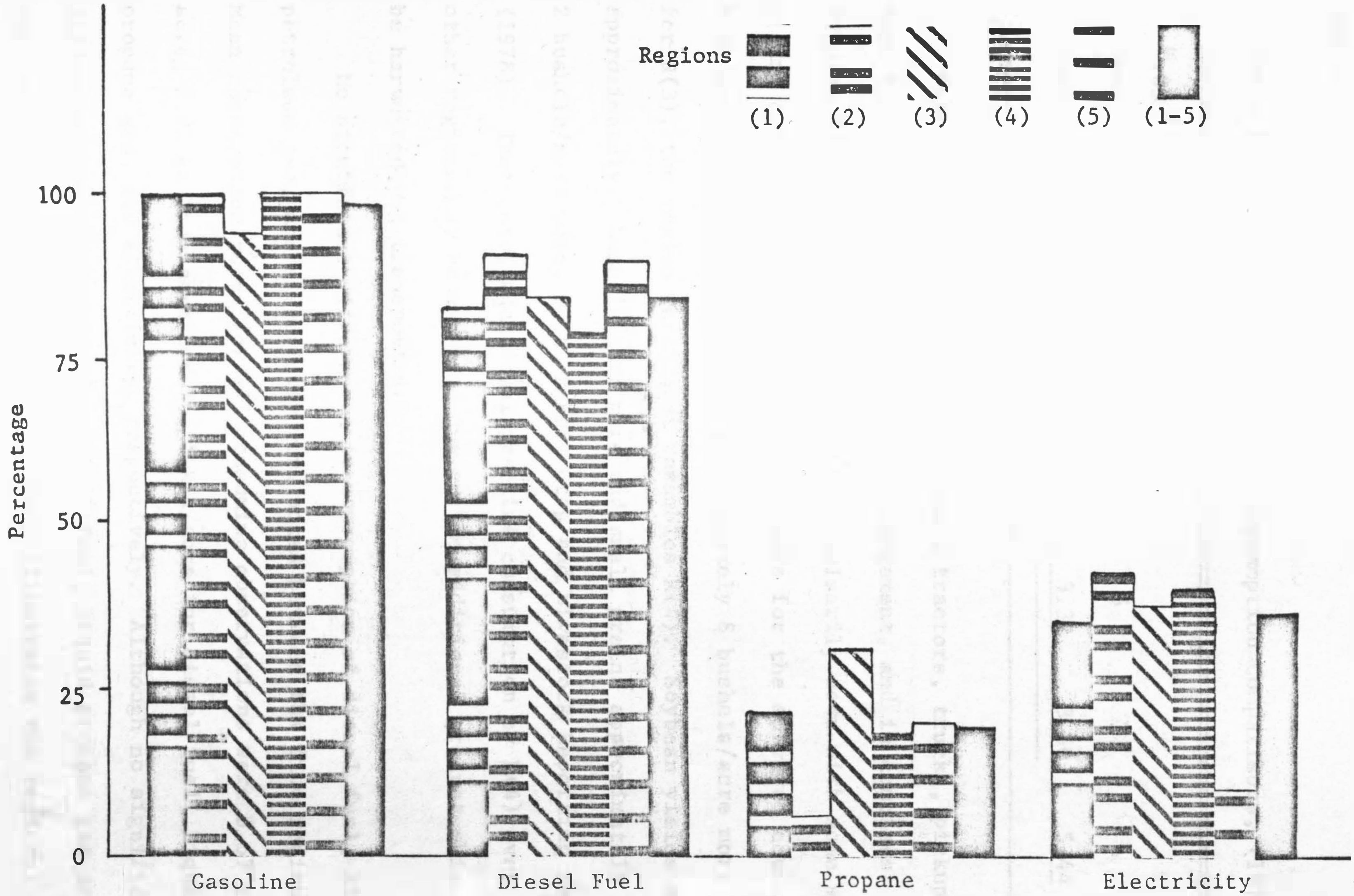

Figure 4. Percentage of Respondents Using Gasoline, Diesel Fuel, Liquid Propane Gas, and Electricity For Eastern South Dakota Crop Production By Region, (1978).

Table 6.

Table 6. Gasoline Regional Mean Consumption Comparisons, (1978).

$\omega_{.05}$ (5, 129)					
Region	2	1	5	3	4
Consumption/acre	3.30	3.32	3.37	3.50	5.44

Gasoline is used primarily in small tractors, trucks, pickups and cars for transportation of crop and management, and in combines. Figures 2 and 3 indicate R(4) produces primarily corn with some small grains also produced. Average corn yields for the surveyed counties in R(4) during 1977 and 1976 were approximately 8 bushels/acre more than for R(3), the region which most resembles R(4). Soybean yields averaged approximately 5 bushels/acre more and small grains approximately 2 bushels/acre more, South Dakota Crop and Livestock Reporting Service (1978). Therefore, additional gasoline consumption by R(4) over the other regions may be expected due to the additional product which must be harvested and transported.

No significant differences in consumption of diesel fuel, liquid petroleum gas, and electricity were noted between the five regions. Mean consumption rates for all consuming observations were 3.67 gallons/acre, 2.95 gallons/acre and 16.25 KWH/acre for diesel fuel, liquid propane gas, and electricity, respectively. Although no significant differences were indicated for diesel fuel, liquid propane gas or electricity, examination of Figure 5, which illustrates the regional consumption levels of gasoline, diesel fuel, liquid propane gas, and

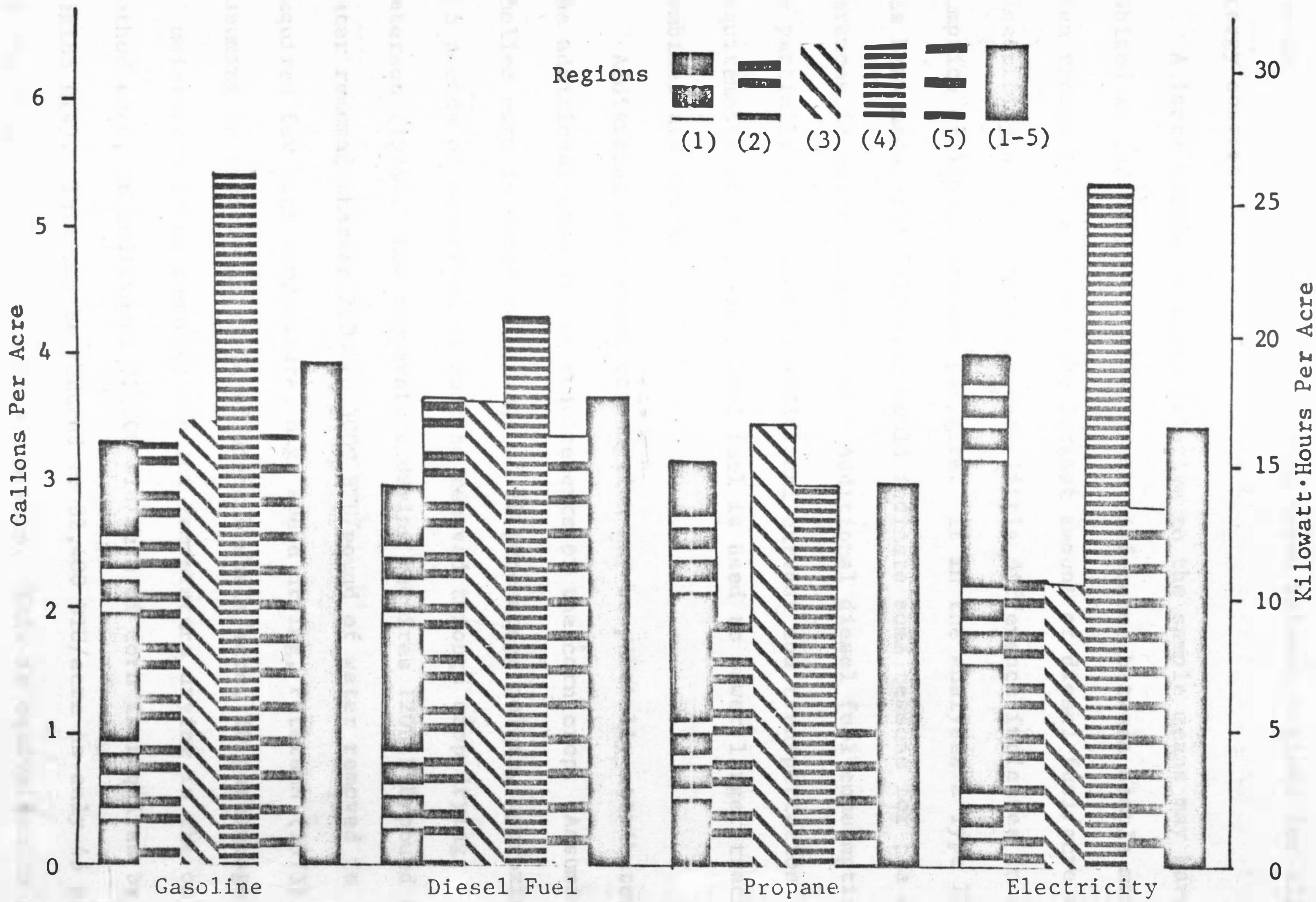

Figure 5. Gasoline, Diesel Fuel, Liquid Propane Gas, and Electricity Consumption/Acre In Eastern South Dakota Crop Production, (1978).

electricity for consumers of the respective energy sources, indicates substantial variation in consumption rates between regions for all energy sources.

A large sample variance relative to the sample means may have prohibited an indication of significant difference between sample means even though R(4) consumed the largest amount of diesel fuel/acre and electricity/acre. There was very little difference indicated in consumption of liquid propane gas/acre. If in the analyses a Type II Error has been made, the following would indicate some reasons for the differences in energy consumption. Additional diesel fuel consumption may be partially attributed to additional harvest and transportation requirements of R(4), as diesel fuel is used to power larger tractors, combines and trucks.

Additional electrical consumption may be partially attributed to the additional crop drying requirements of the corn crop. Assuming that shelled corn is dried an average of 10 percentage points, approximately 7.5 pounds of water/bushel must be removed through crop drying, Peterson (1978). Low temperature drying requires 1200 BTU/pound of water removed whereas 2000 to 3000 BTU/pound of water removed is required for high temperature, high speed drying, Peterson (1973). Assuming an additional yield of eight bushels/acre, 10 percentage points of moisture must be removed, and low temperature drying is the only method used, an additional 72,000 BTU/acre of corn is required by region R(4). This may be reduced to 32,400 BTU/acre as only 45 percent of the total crop acres in R(4) are corn. This is equivalent to an extra requirement of 9.5 KWH/acre. It must be recognized, however, that all of the corn was not dried on the farm. Additional handling of corn from the dryer to the first storage location as well as additional aeration requirements may also account for part of the additional electrical usage. It may be unrealistic to assume, however, that the above reasons explain all of the difference between R(4) and the other regions.

Examination of Figure 5 indicates regions R(4) and R(3) ranked first and second, first and third, and first and second in consumption rates of gasoline, diesel fuel, and liquid propane gas, respectively. This may be expected as the proportion of corn relative to other crops is highest for the two regions, Figure 3. Corn production requires weed control through cultivation or chemicals. As corn is a late season crop, it often requires artificial drying for preservation or chemical treatment, this would cause liquid propane gas consumption and electricity consumption to increase. Figure 5 indicates R(4) consumed the largest amount of electricity/acre, which is what may be expected, however, Figure 5 also indicates R(3) consumed the least electricity/acre which is contrary to what is expected. The only explanation which can be offered is the large variance and small sample size experienced by the survey may have yielded biased results.

Appendix Tables E_1 through E_4 summarize the analyses of variance for eastern South Dakota fertilizer consumption by region and crop. The analyses use fertilizer type as the dependent variable. The analyses of fertilizer consumption consider all operations producing a given crop.

No significant difference among regions in consumption/acre of N, P_2O_5, or K_2O existed for corn production. The mean application rates/acre for corn production were 36.7 pounds/acre, 15.3 pounds/acre, and 4.5 pounds/acre for N, P_2O_5 and K_2O, respectively. Figure 6 illustrates the mean fertilizer application rates for eastern South Dakota corn production during 1978. The percentages of corn producers which applied the various forms of fertilizer in corn production were N - 57 percent, P_2O_5 - 45 percent, and K - 24 percent.

No significant difference among regions in consumption/acre of N, P_2O_5 or K_2O existed for soybean production. The mean fertilizer application rates/acre were 3.3 pounds/acre, 3.3 pounds/acre, and 2.3 pounds/acre respectively for all farms producing soybeans during 1978. Figure 7 illustrates the fertilizer consumption levels/acre for eastern South Dakota soybean production during 1978. The percentages of soybean producers which applied the various forms of fertilizer in soybean production were N - 13 percent, P_2O_5 - 13 percent, and K_2O - 13 percent.

No significant difference among regions in consumption/acre of N existed for small grain production in eastern South Dakota during 1978. The mean nitrogen application rate for small grain production was 24.0 pounds/acre. Production region had a highly significant effect on P_2O_5 and K_2O consumption/acre for small grain production, Tables 7 and 8.

Table 7. P_2O_5 Regional Mean Consumption Comparisons for Small Grains, (1978).

$\omega_{.05}$ (5, 121)					
Region	1	5	3	4	2
Consumption/acre	4.62	10.00	17.10	17.97	20.70

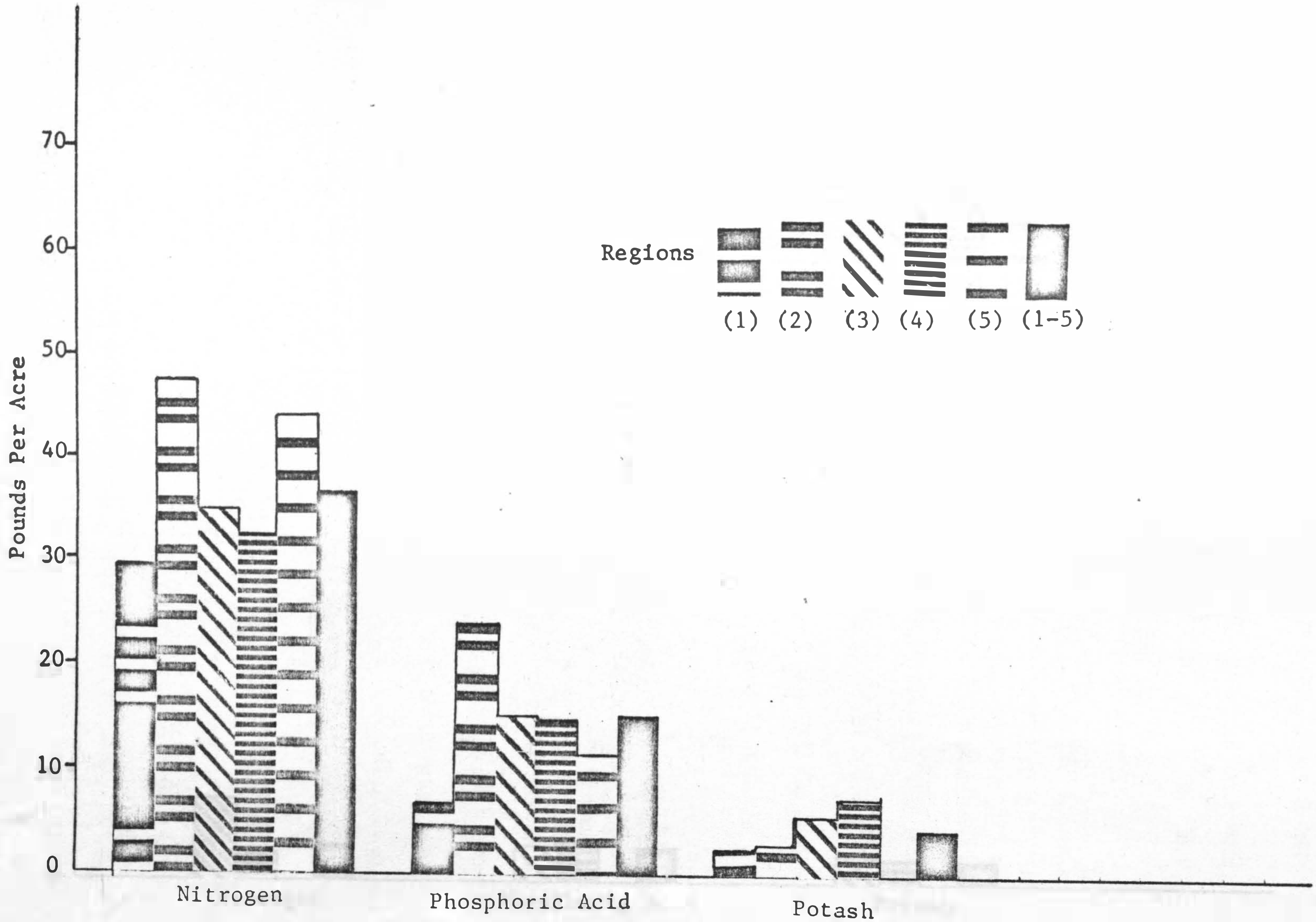

Figure 6. Fertilizer Consumption/Acre For Corn Production In Eastern South Dakota By Region, (1978).

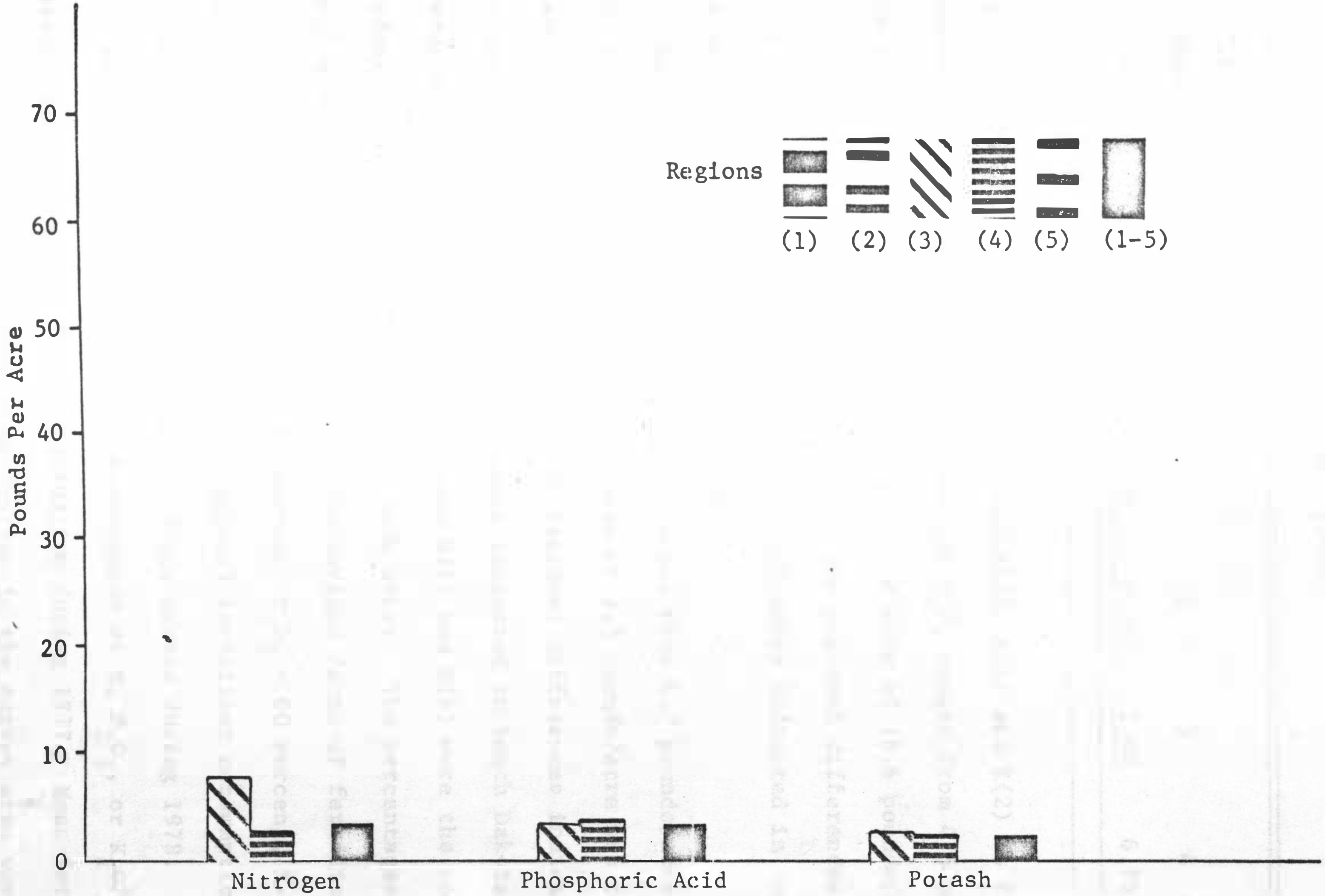

Figure 7. Fertilizer Consumption/Acre For Soybean Production In Eastern South Dakota By Region, (1978).

Table 8. K_2O Regional Mean Consumption Comparisons for Small Grains, (1978).

$\omega_{.05}$ (5, 121)					
Region	1	5	2	3	4
Consumption/acre	0.71	1.00	2.79	2.90	6.75

Region R(1) was significantly lower than R(3), R(4) and R(2) in P_2O_5 consumption. Average application rates of P_2O_5 ranged from 4.6 pounds/acre in R(1) to 20.7 pounds/acre in R(2). A mean of 15.6 pounds/acre was consumed by the 126 farms analyzed. The regional differences indicated are consistent with phosphorus deficiencies indicated in South Dakota soil tests, Ward and Carson (1975).

Average application rates of K_2O ranged from 0.7 pounds/acre in R(1) to 6.8 pounds/acre in R(4). A mean of 3.3 pounds/acre was consumed by the 126 farms analyzed. The regional differences indicated are consistent with potash deficiencies indicated in South Dakota soil tests, Ward and Carson (1975). Regions R(1) and R(4) were the only regions significantly different from each other. The percentages of small grain producers which applied the various forms of fertilizer in small grain production were N - 68 percent, P_2O_5 - 60 percent, K - 28 percent. Figure 8 illustrates the regional fertilizer consumption/acre for small grain production in eastern South Dakota during 1978.

No significant difference in consumption of N, P_2O_5, or K_2O/acre existed between regions for hay production during 1977. Mean fertilizer consumption levels for hay production in the survey area were as follows: N - 4.7 pounds/acre; P_2O_5 - 9.9 pounds/acre and K_2O - 1.3

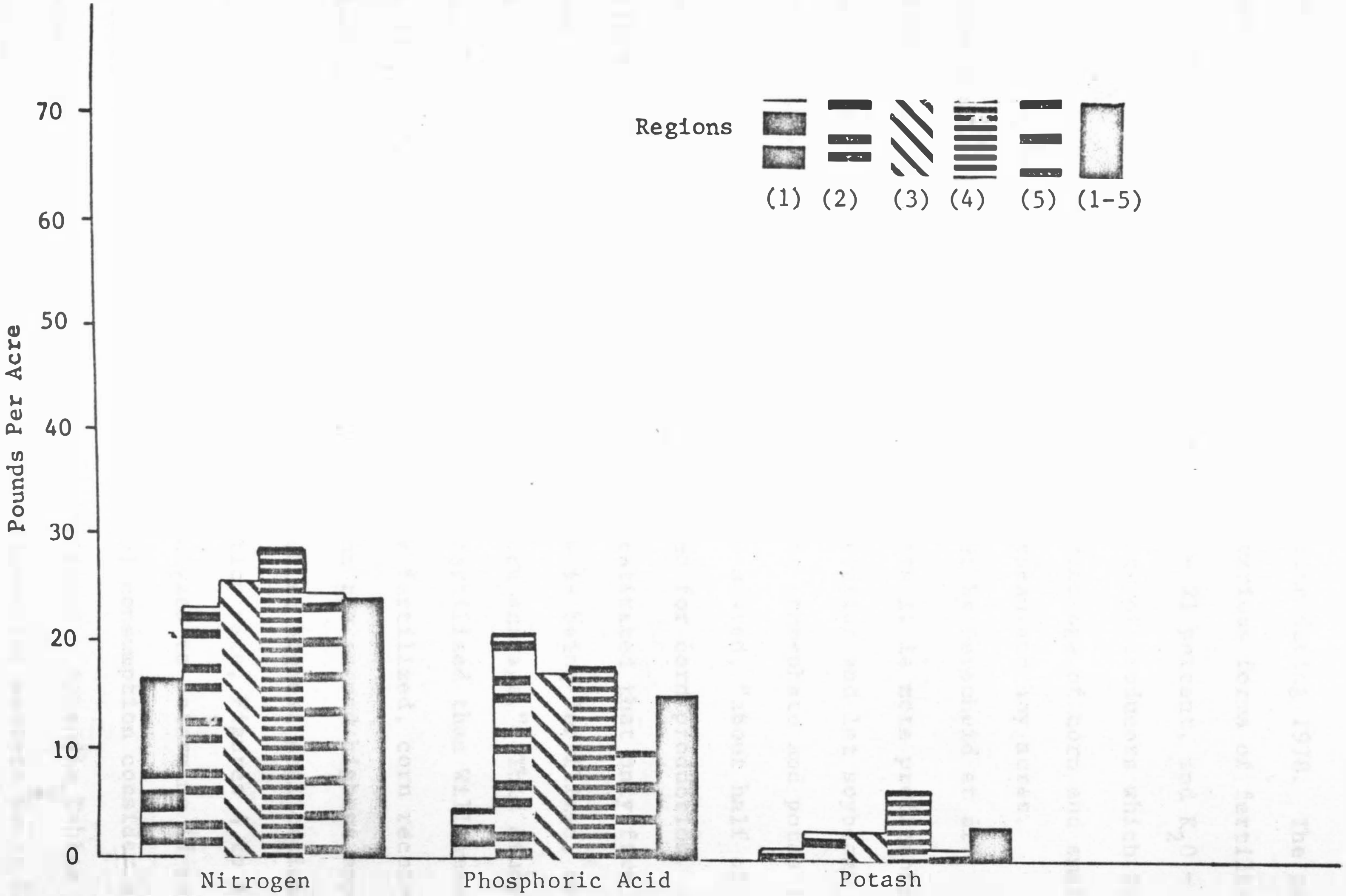

Figure 8. Fertilizer Consumption/Acre For Small Grain Production In Eastern South Dakota By Region, (1978).

pounds/acre. Figure 9 illustrates the fertilizer consumption levels/acre for eastern South Dakota hay production during 1978. The percentages of hay producers which applied the various forms of fertilizer in hay production were N - 17 percent, P_2O_5 - 21 percent, and K_2O - 8 percent. Figure 11 illustrates the percentage of producers which fertilized the crop in question. A greater percentage of corn and small grain acres were fertilized than were soybean and hay acres. These results are consistent with a report by Derscheid et al. (1969) that stated, "Some evidence suggests it is more profitable to apply fertilizer to other crops in the rotation and let soybeans obtain their nutrient needs of these two elements (phosphate and potash) from residual carryover." Adams et al. (1978) stated, "about half of the fertilizer applied in South Dakota is used for corn production." Williamson et al. (1977) stated, "It is estimated that only five percent of the tame hay and pasture area now is being fertilized, compared to fertilizer use on 23 percent of the corn acreage." This study, however, found a higher percentage of corn fertilized than Williamson et al. (1977) indicated. When crops were fertilized, corn received the highest application rate, small grains the second highest application rate, hay and alfalfa received the third highest application rate and soybeans received the lowest application rate, Figures 4 to 6.

Chemical consumption by crop was analyzed to determine if regional effects existed. The analyses of chemical consumption consider all operations producing the crop being considered. Appendix Tables F_1 through F_4 summarize the analyses of variance for eastern South Dakota chemical consumption as it applies to corn, soybeans, small grains, and

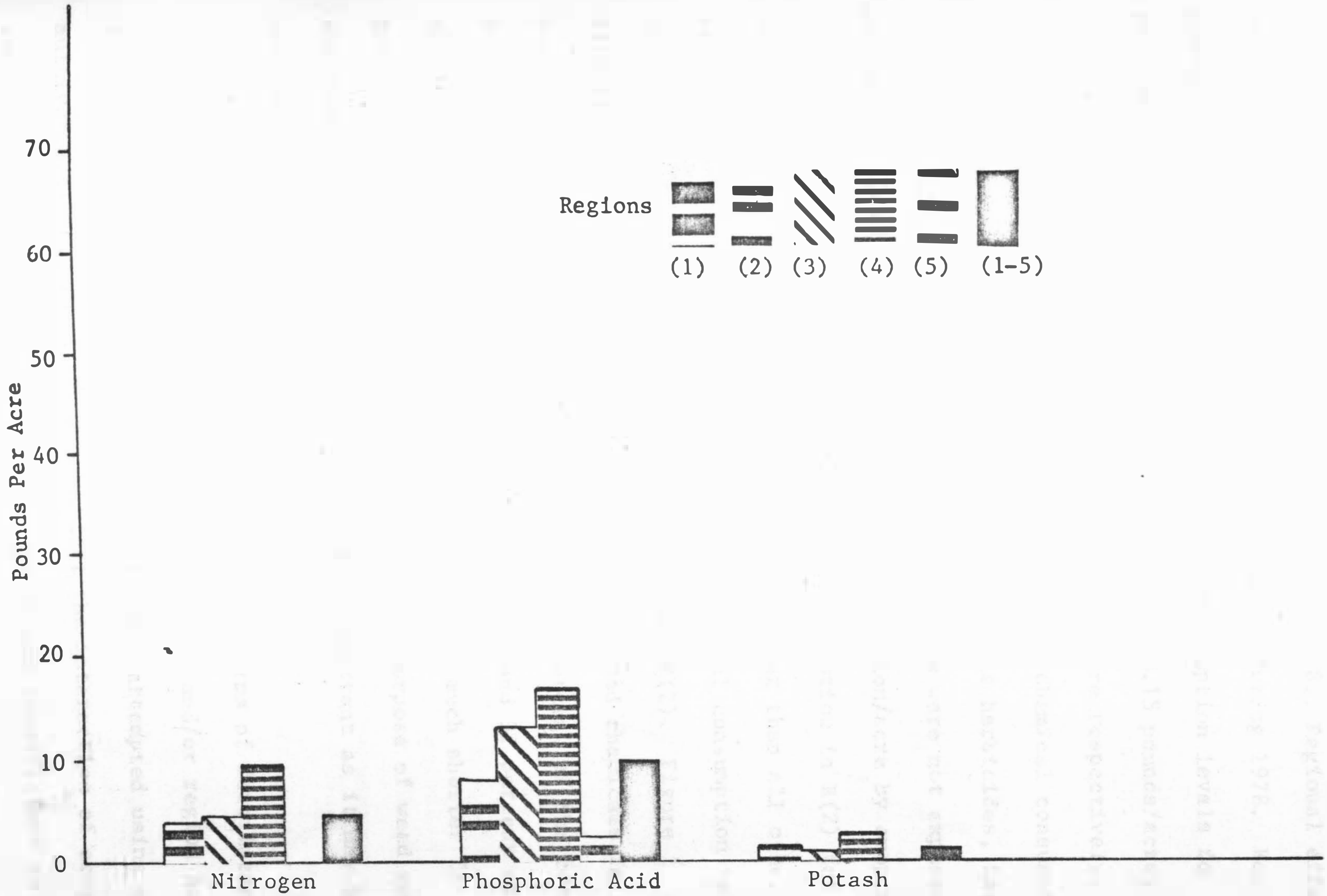

Figure 9. Fertilizer Consumption/Acre For Hay and Alfalfa Production In Eastern South Dakota By Region, (1978).

hay production respectively, by region during 1978. Regional effects were insignificant for all crops being produced during 1978. For the aggregate of all regions the mean chemical consumption levels for corn, soybeans, small grains, and hay production were 3.15 pounds/acre, 2.60 pounds/acre, 0.46 pounds/acre, and 0.00 pounds/acre respectively. There were no chemicals used in hay production. Chemical consumption occurs primarily in the form of pesticides such as herbicides, insecticides and fungicides. Regional consumption rates were not expected to differ. Figure 10 illustrates chemical consumption/acre by crop and region. In examining Figure 10, chemical consumption in R(2) for soybean production appears to be substantially higher than all other regions, however, only one observation of chemical consumption in soybean production was available for both R(1) and R(2). Figure 11 also illustrates the percentage of operations which used chemicals in crop production by crop. Chemicals were used by 44 percent of the corn producers, 46 percent of the soybean producers, and 32 percent of the small grain producers. As the growing season is much shorter for small grain production, chemical consumption for the purpose of weed control and insect control may not be considered as important as it may be in corn and soybean production.

Total energy (kcal/acre) consumed in the forms of fertilizers and chemicals was analyzed to determine if crop type and/or region had an influence on consumption rate. An analysis was attempted using a multivariate analysis of variance to test the interaction of crops and regions, however, the number of observations was insufficient to provide usable results. Appendix Table G summarizes the analyses of

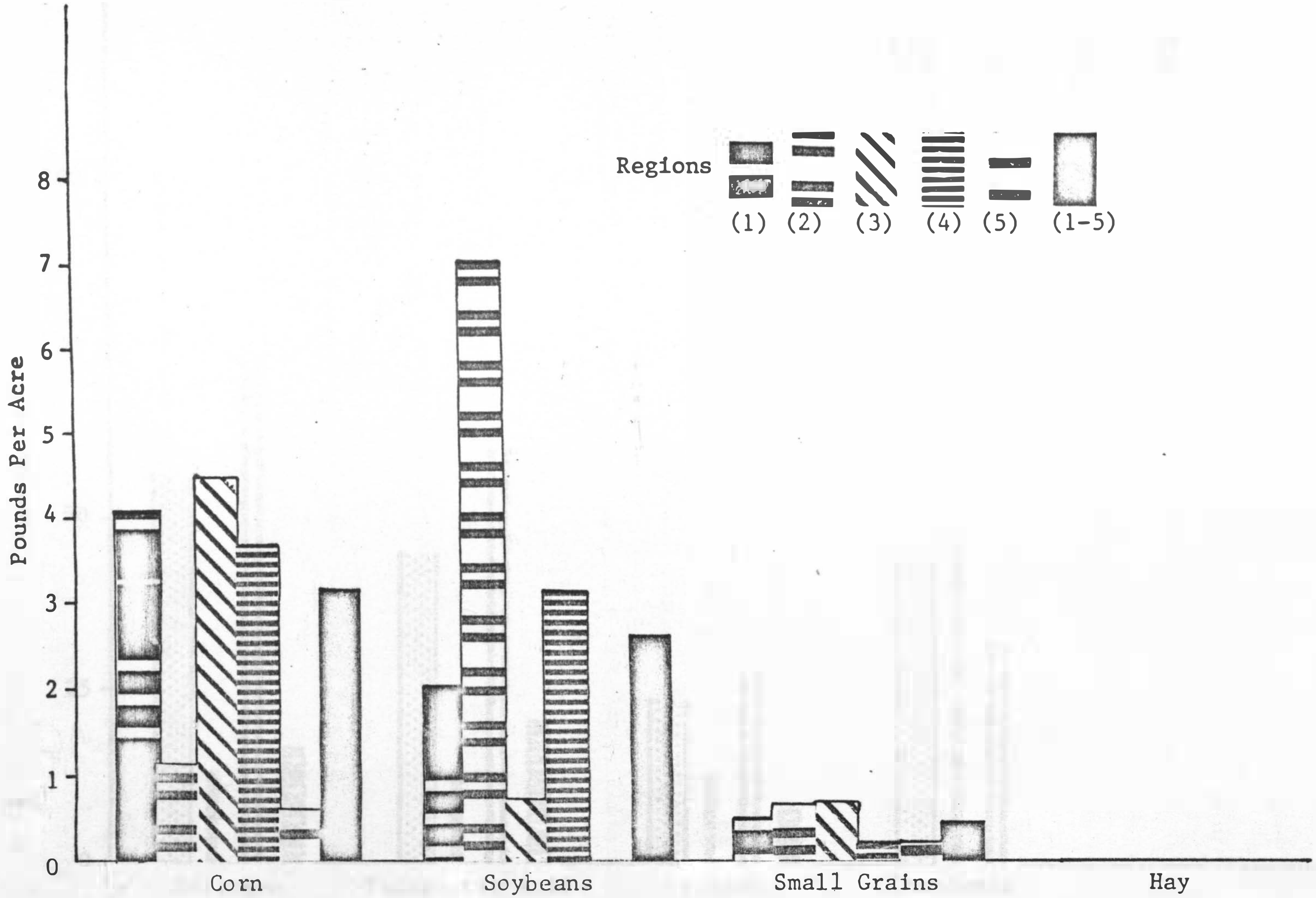

Figure 10. Chemical Consumption/Acre For Crop Production in Eastern South Dakota By Region and Crop Type, (1978).

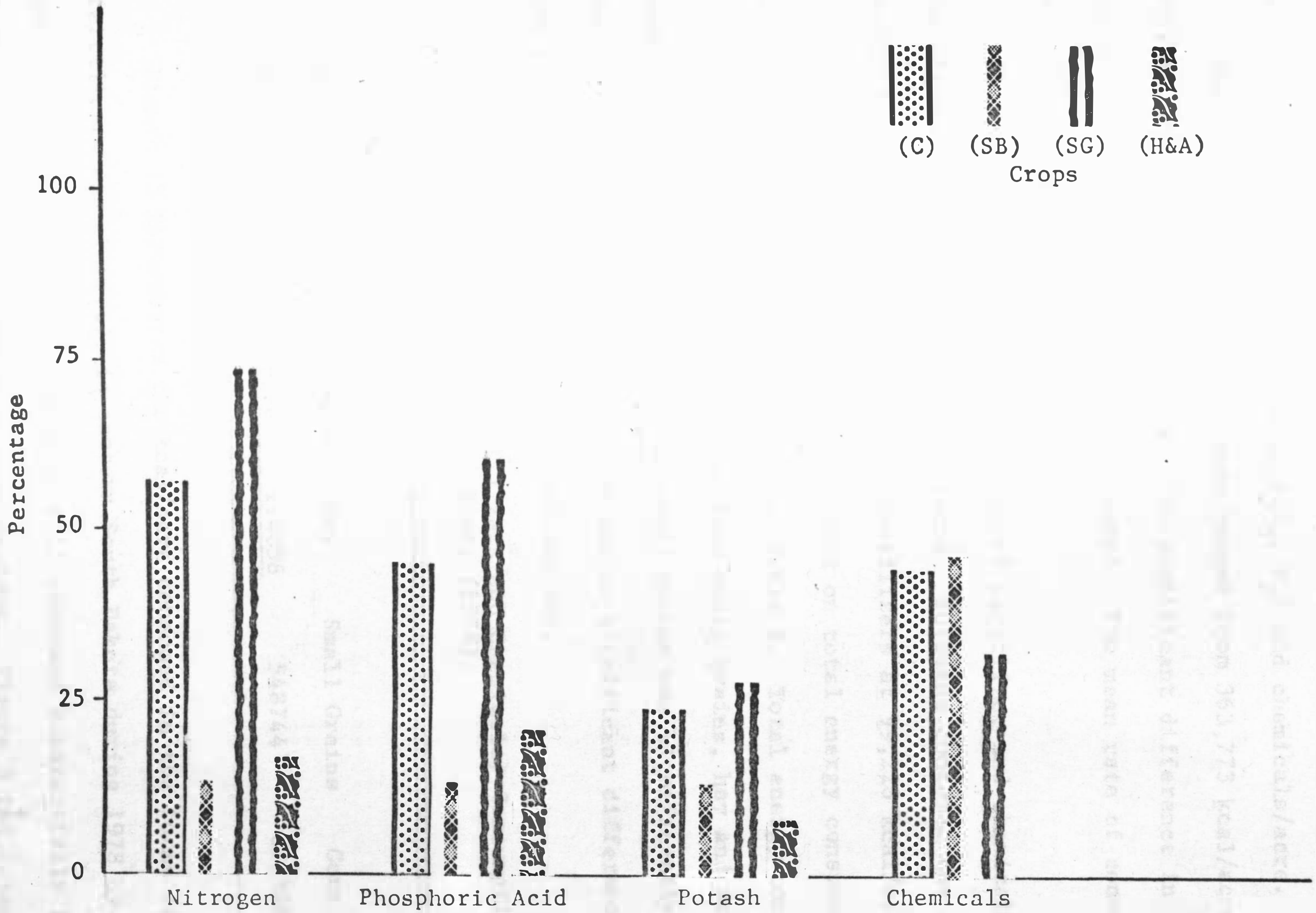

Figure 11. Percentage of Operations In Eastern South Dakota which Consumed Fertilizers and Chemicals In Producing A Crop By Crop Type and Fertilizer Type, (1978).

variance for chemical and fertilizer consumption by region and crop using the summation of kcals of N, P_2O_5, K_2O and chemicals/acre.

Mean regional consumption rates ranged from 363,773 kcal/acre in R(1) to 541,457 kcal/acre in R(2). No significant difference in regional consumption levels was indicated. The mean rate of consumption was 506,043 kcal/acre.

Consumption of energy in the form of fertilizer and chemicals was the highest by corn at 877,320 kcal/acre. Soybeans consumed the least energy in the form of chemicals and fertilizers at 99,226 kcal/acre. Crop type had a highly significant affect on total energy consumed in the forms of fertilizer and chemicals, Table 9. Total energy consumed by corn was significantly different from small grains, hay and soybeans; also, the total energy consumed by small grains was significantly different from hay and soybeans. There was no significant difference in the total energy consumed by soybeans and hay.

Table 9. Total Energy (Fertilizers and Chemicals) Consumption Comparisons by Crop Type, (1978).

$\omega_{.05}$ (4, 382)

Crop	Soybeans	Hay	Small Grains	Corn
Consumption/acre	99226	114856	548744	877320

Figure 12 illustrates the kcal/acre consumed in the forms of fertilizers and chemicals in eastern South Dakota during 1978 by region and crop type. Figure 12 indicates R(1) consumed substantially less total energy than did the other four regions. Figure 3 indicates R(1) produces predominately small grains. Figures 6 and 8 indicated the

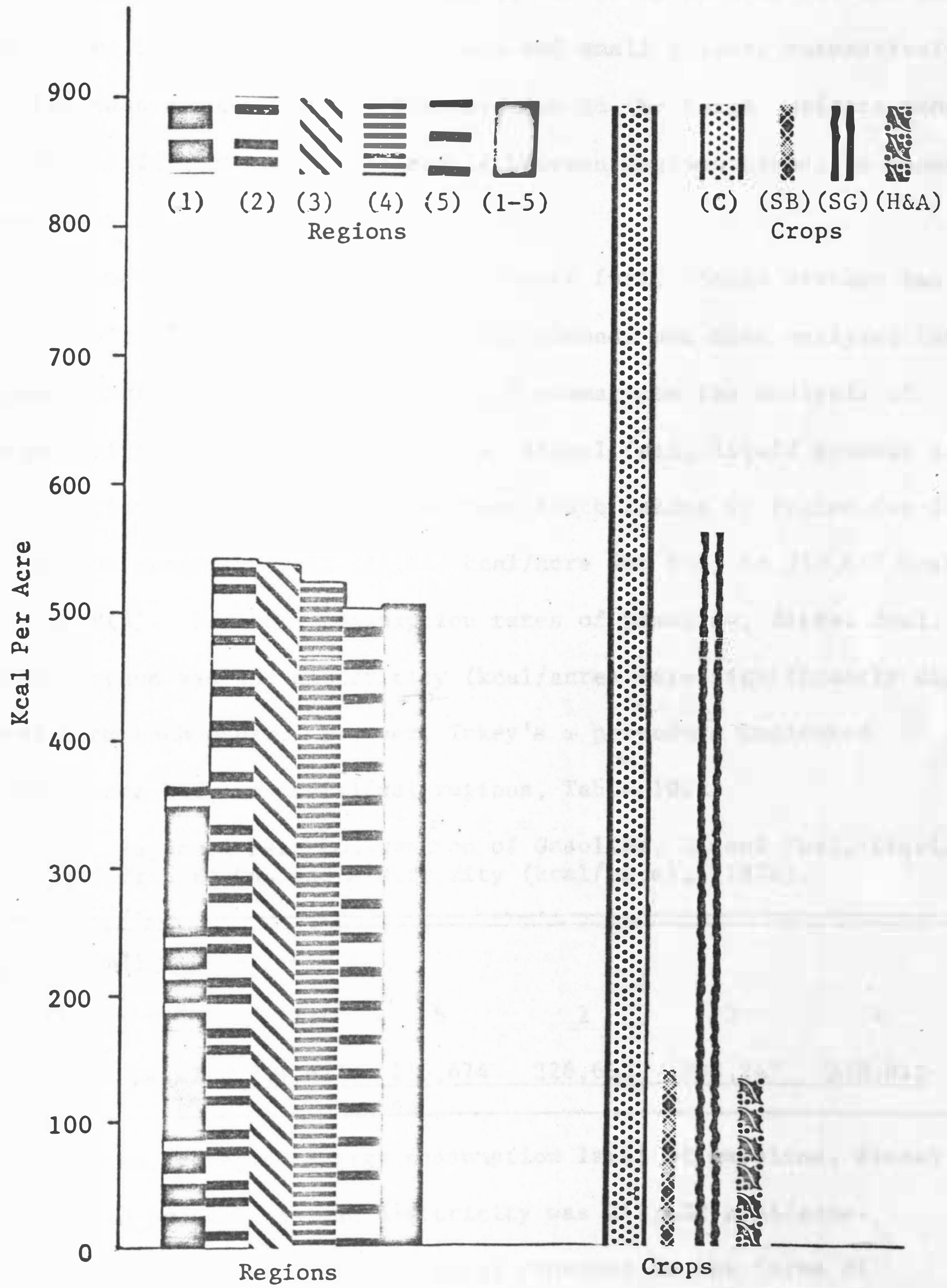

Figure 12: Energy Consumed In The Forms of Fertilizers and Chemicals In Eastern South Dakota Crop Production By Region and Crop, (1977).

application rates of the various fertilizer forms by R(1) for the two most energy intensive crop types, corn and small grains, respectively, was the least of any region. However, due to the large variance among samples within regions the difference between regions cannot be shown to be significant.

Consumption levels of gasoline, diesel fuel, liquid propane gas and electricity were converted to kcal, summed, and then analyzed for regional differences. Appendix Table H summarizes the analysis of variance of the summation of gasoline, diesel fuel, liquid propane gas and electricity (kcal/acre) for eastern South Dakota by region for 1978. Consumption ranged between 211,617 kcal/acre for R(1) to 310,812 kcal/acre for R(4). Regional consumption rates of gasoline, diesel fuel, liquid propane gas and electricity (kcal/acre) were significantly different from each other. However, Tukey's ω procedure indicated no difference between individual regions, Table 10.

Table 10. Regional Mean Consumption of Gasoline, Diesel Fuel, Liquid Propane Gas and Electricity (kcal/acre), (1978).

$\omega_{.05}$ (5, 131)					
Regions	1	5	2	3	4
Consumption Level	211,617	216,674	226,663	238,247	310,812

The mean aggregate energy consumption level of gasoline, diesel fuel, liquid propane gas and electricity was 249,622 kcal/acre. Figure 13 illustrates the total energy consumed in the forms of gasoline, diesel fuel, liquid propane gas and electricity. Figure 13 indicates R(4) is higher than the other four regions. This may be

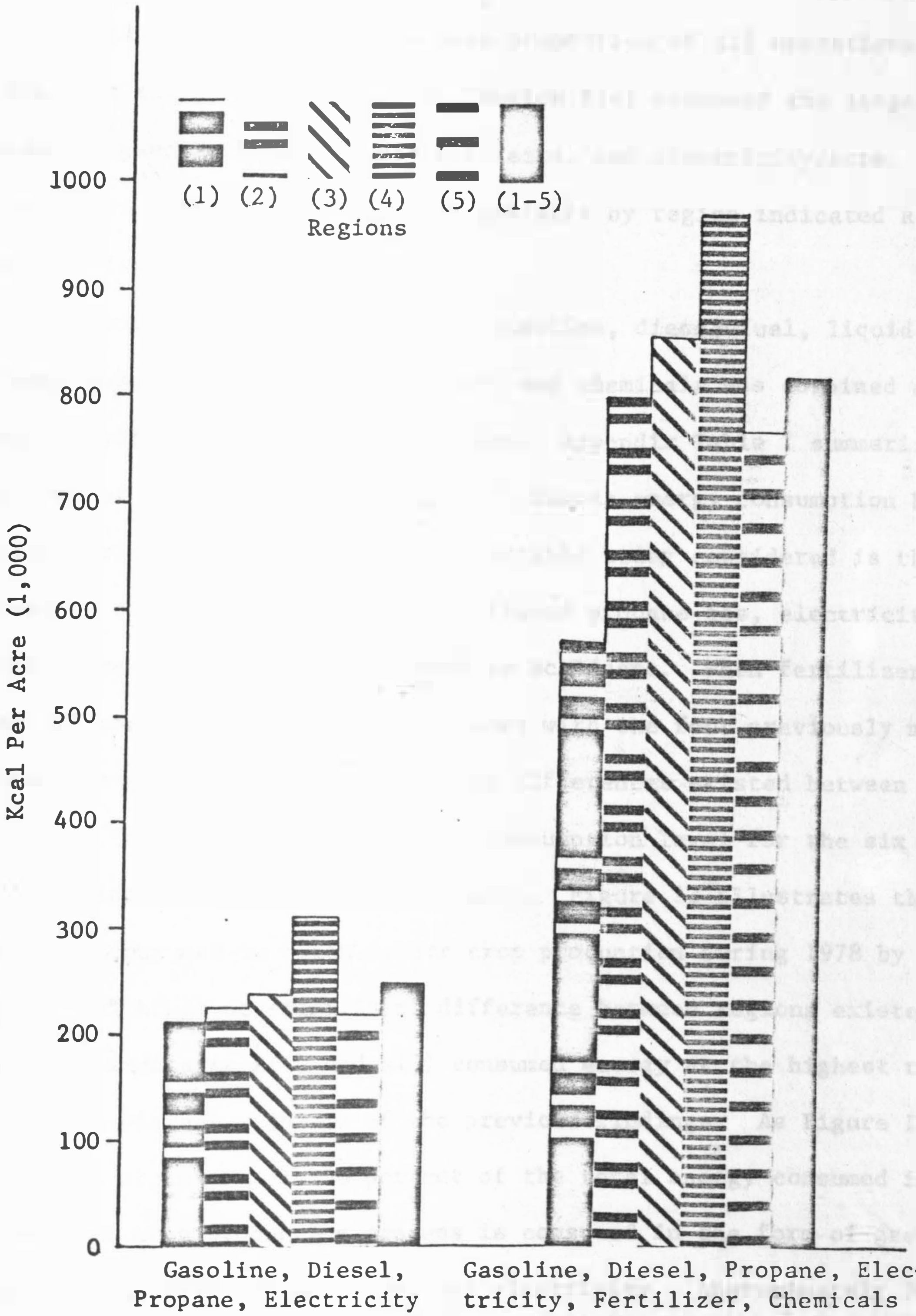

Figure 13. Total Energy Consumed In Eastern South Dakota In The "On Farm" Production Process, (1978).

expected as the proportion of operations using various energy types in R(4) was closely related to the mean proportion of all operations using a specific energy form, Figure 4. Region R(4) consumed the largest amount of gasoline/acre, diesel fuel/acre, and electricity/acre. The consumption rate of liquid propane gas/acre by region indicated R(4) ranked third.

The energy used in the form of gasoline, diesel fuel, liquid propane gas, electricity, fertilizers and chemicals was combined and then analyzed for regional differences. Appendix Table I summarizes the analysis of variance for eastern South Dakota energy consumption by region during 1978. The dependent variable being considered is the summation of gasoline, diesel fuel, liquid propane gas, electricity, fertilizers and chemicals converted to kcal/acre. When fertilizer and chemical consumption were also included with the four previously mentioned energy sources, no significant differences existed between regions. The mean aggregate energy consumption level for the six energy sources discussed was 823,200 kcal/acre. Figure 13 illustrates the kcal/acre consumed in South Dakota crop production during 1978 by region. Although no significant difference between regions existed, Figure 13 indicates R(4) and R(3) consumed energy at the highest rate. This is consistent with all of the previous findings. As Figure 13 indicates, approximately 30 percent of the total energy consumed in the on-farm crop production process is consumed in the form of gasoline, diesel fuel, liquid propane gas, and electricity. Approximately 70 percent of the total energy consumed is consumed in the form of fertilizers and chemicals. The two most energy intensive crop types, corn and small grains, comprised 72.8 percent of the total crop acreage.

CONCLUSIONS

The following conclusions were reached during this study. Conclusions are based upon limited returns to the survey questions, and therefore the probability of biased results is increased.

1) Regional differences do exist for the level of gasoline consumption. Region R(2) consumed the least gasoline/acre and R(4) consumed the most gasoline/acre. Using 1977 farm input price levels, Economics, Statistics and Cooperative Service USDA, (1977), and the conversion ratio suggested by Frith and Promersberger, (1974), the MP_G/P_G = 2.14 (G = gasoline) and the MP_D/P_D = 3.18 (D = diesel fuel). Therefore the $\frac{MP_G}{P_G} < \frac{MP_D}{P_D}$ implying that substitution to diesel fuel will occur more rapidly in R(4) than in R(2). It must be recognized that the higher the purchase costs which diesel powered machinery present and the higher the interest rates present, the slower will be the conversion process.
2) All regions were primarily dependent upon gasoline and diesel fuel for providing the energy source necessary for crop production.
3) Regional differences do not exist for fertilization rates for corn, soybeans and hay, therefore mean aggregate application rates apply for the individual crops.
4) Nitrogen application rates for small grain production did not differ among regions, therefore mean aggregate application rates apply for all regions.
5) Regional differences do exist for application rates of P_2O_5 and

K_2O in small grain production. Regions R(2) and R(4) consumed the largest amount of each respectively and therefore small grain production in R(2) and R(4) could be influenced by unit cost changes of these inputs.

6) Regional differences do not exist for application rates of chemicals. Therefore, mean aggregate application rates apply for all regions for a given crop.

7) When fertilizer and chemical consumption only are considered, corn is the most energy intensive crop, and small grains are the second most energy intensive crop. Changes in energy input prices and availability will therefore alter South Dakota crop mix or output levels. As energy prices increase, ceterius paribus, reduced fertilization, and a substitution to less energy intensive crops will occur.

8) Regional differences do not exist for the total amount of energy consumed by regions for crop production. Therefore, aggregate mean consumption levels apply for all regions.

9) Fertilizers and chemicals account for 70 percent of the energy consumed in South Dakota dry land crop production. Changes in the price or availability of these energy resources will have effects on South Dakota crop production. As the price of these inputs increase, ceterius paribus, or as physical quantity constraints occur, a reduction in the use of the inputs will occur and land and labor may be substituted for fertilizer and chemicals. Reduced yields may occur, causing reduced revenues. If total net revenue decreases, substitution to less energy intensive crops will

occur, provided those crops yield a higher net return than does the previous crop.

10) Crop mix does differ by region. Therefore, regional adjustments to energy resource availability and price will differ.

11) The two most energy intensive crops, corn and small grains, comprise from 61.6 percent to 84.3 percent of any regions total crop mix. Therefore, changes in the availability or price of energy inputs for these crops will affect all regions.

12) Regions R(2) and R(3) are most heavily dependent upon energy intensive crops. Therefore, changes in crop mix will occur primarily in these regions, if changes in energy availability or price occur. Crop mix changes will be primarily dependent upon expected production levels of various crops, price of the crop being produced, prices of substitute crops and prices of energy inputs.

13) Substitution of land for energy inputs, especially fertilizers and chemicals, may occur prior to crop mix changes, if energy price and physical constraints are applied.

14) Where only one crop was produced by a respondent, insufficient returns were obtained for an analysis of the input levels of gasoline, diesel fuel, liquid propane gas and electricity. Therefore, consumption of these inputs could not be correlated with production of given crops.

15) Survey techniques other than mail-out questionnaires should be used when possible.

SUMMARY

A field survey of eastern South Dakota farms was conducted during the last quarter of 1978 to study the effects of location and crop mix on energy consumption. The economic impact of price or physical constraints on energy related inputs was studied to determine what effects the constraints will have on crop mix and output levels. The survey design consisted of a mail-out questionnaire sent to 1500 farmers and ranchers in ten counties which were considered representative of five regions in eastern South Dakota. Two counties for each region were sampled through a random sampling procedure.

Energy sources studied were gasoline, diesel fuel, liquid propane gas, electricity, fertilizers N, P_2O_5 and K_2O, and chemicals. Crops studied were corn, soybeans, small grains, and hay and alfalfa. Two energy intensive operations, irrigation and crop drying, were to also be studied. However, insufficient returns for the two operations prohibited the analyses.

Analyses of variance indicated regional effects are evident in gasoline consumption, P_2O_5 and K_2O consumption for small grain production, and chemical consumption for soybean production. Regional differences also existed in the mean number of acres produced/observation of corn, soybeans, small grains, and hay and alfalfa. Energy consumption, in the form of fertilizers and chemicals, when compared by crop, indicated corn and small grains were energy intensive crop types. Therefore, regional adjustments to physical or price constraints would be expected to be different.

The successes and failures of this study may be used as guidelines for future agriculture energy consumption surveys. The study results apply only to eastern South Dakota and interpretation for, and application of the results to other regions should be attempted only with great caution.

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APPENDIX A

SOUTH DAKOTA STATE UNIVERSITY
BROOKINGS, SOUTH DAKOTA 57006

COLLEGE OF ENGINEERING

AGRICULTURAL ENGINEERING DEPARTMENT

October 1, 1978

Dear Sir:

I am currently engaged in a survey of South Dakota farmers and would like to ask your assistance in this effort. You have been selected, by a random sampling method, to assist in the survey concerning total fuel consumption in crop production by eastern South Dakota farmers.

The survey is being conducted to provide information for a thesis paper being written by myself, a graduate student.

Your questionnaire has been assigned a number. The number has been provided to maintain the confidentiality of your questionnaire. Would you please complete the questionnaire and return to be by December 15? A follow-up questionnaire will be sent to those individuals whose questionnaire we do not receive by this date.

Please give total figures in the questionnaire where asked. We will convert all figures to a per acre or per head basis.

We hope the information obtained will be of substantial benefit to South Dakota farmers upon completion of the survey.

I would like to take this opportunity to thank you for your assistance in this effort. If you would like a copy of these results, please indicate this on the questionnaire.

Sincerely yours,

Terry Rydell

Terry Rydell, Grad. Research Assistant
Agricultural Engineering Department

TR/js

SOUTH DAKOTA FARM FUEL AND ENERGY CONSUMPTION SURVEY

I was ( ) was not ( ) actively engaged in farming in 1978. (Check one)

1978 Total Fuel Consumption

Please include all fuel and energy which was purchased, on or off the farm, for farm use. Include fuel purchases for custom work. (Estimate if necessary.) Note: Exclude residential use in estimates.

Classifications	Energy Types			
	Gasoline	Diesel	Propane	Electricity
What was your total consumption in 1978 of: (include farm consumption only)	(Gal.)	(Gal.)	(Gal.)	(Kilowatts)
How much energy was used for 1978 CROP PRODUCTION? (Includes harvesting, irrigating, drying, and transportation to first storage location even if crop was meant to be fed to livestock)	(Gal.)	(Gal.)	(Gal.)	(Kilowatts)
How much energy was used for LIVESTOCK PRODUCTION?	(Gal.)	(Gal.)	(Gal.)	(Kilowatts)
GENERAL FARM USE (Includes farm car and pickup use)	(Gal.)	(Gal.)	(Gal.)	(Kilowatts)

LIVESTOCK PRODUCTION TYPE AND SIZE: Number of head

Cattle	0 ___	10-200 ___	200-500 ___	500-1000 ___	1000+ ___
Hogs	0 ___	10-200 ___	200-500 ___	500-1000 ___	1000+ ___
Dairy	0 ___	10-200 ___	200-500 ___	500-1000 ___	1000+ ___

CROP PRODUCTION: (Include total acres, total fertilizer used and total chemicals used even if farmed on a share basis.

Crop Type	Acres Farmed in 1978	Average lbs. Fertilizer Used Per Acre			Chemicals Used Per Acre	
		Nitrogen (lbs.)	Phosphorus (lbs.)	Potash (lbs.)	Type	Amount
Corn	acres					lbs. lbs.
Soybeans	acres					lbs. lbs.
Small Grains	acres					lbs. lbs.
Hay & Alfalfa	acres					lbs. lbs.

IRRIGATION IN 1978

Did you irrigate in 1978: Yes ( ) No ( )

Type of Crop	Number of Acres Irrigated	Type of Irrigation System Used	Type of Energy Used	Amount of Energy Used

CROP DRYING IN 1977: 1977 information is requested for crop drying as information from the survey is needed back at this office prior to the end of the 1978 crop drying season. Did you dry any crops in 1977? Yes ( ) No ( )

(Include any custom drying you may have done)

Type of Crop	Number of Bushels Dried in 1977	% of Moisture Removed	Type of Energy Used	Amount of Energy Used

Would you like a copy of the survey results? Yes ____ No ____

COMMENTS:

APPENDIX B

REGION	FARM	TOTAL CONSUMPTION-CROP PRODUCTION				ACRES			
		GASOLINE(GAL)	DIESEL(GAL)	PROPANE(GAL)	ELECTRICITY(KW-H)	CORN	S BEANS	S GRAIN	HGA
4	1	1200	0	0	0	50	0	40	13
4	2	1630	560	0	0	98	12	85	49
4	3	350	0	0	0	16	0	20	35
4	4	30	500	0	0	60	40	0	10
4	5	1000	1200	0	0	100	35	65	20
4	6	5000	0	0	15000	150	0	50	50
4	7	2200	500	0	0	50	105	0	172
4	8	2000	3500	0	5000	270	140	0	0
4	9	900	1000	0	10000	220	45	0	120
4	10	2500	1250	0	2000	270	80	180	50
4	11	970	660	0	0	160	0	116	107
4	12	350	800	0	0	100	0	104	39
4	130	80000	35000	20000	*****	500	0	500	300
4	140	20000	9000	0	*****	170	0	51	25
4	15	1200	1400	0	1000	260	0	85	90
4	16	1180	0	0	0	64	0	53	44
4	17	1000	0	0	0	85	0	120	40
4	18	300	750	150	1500	40	10	42	20
4	19	2100	1800	0	0	260	90	180	20
3	20	800	100	0	0	90	0	70	40
3	21	200	2100	0	0	350	0	170	0
3	22	0	2000	2000	15000	223	0	200	15
3	23	600	475	0	0	150	0	150	60
3	24	550	1900	0	580	135	0	260	0
3	25	2000	4000	4000	10000	300	130	250	50
3	26	1700	1500	1000	0	153	0	165	30
2	27	1340	2160	0	0	35	0	360	125
2	28	1418	4527	0	13530	100	0	700	80
2	29	139	490	0	1620	25	0	160	35
2	30	1600	850	0	9600	0	0	400	20
2	31	4600	3600	0	0	90	0	415	130
2	32	800	0	0	0	0	0	87	2
2	33	600	4600	0	25000	75	0	380	50
2	34	3000	1000	0	40000	65	0	300	97
2	35	3000	3000	1000	0	65	0	425	0
2	36	2947	1145	0	755	76	0	456	148
2	37	400	800	0	1000	0	0	316	190
2	38	3800	500	0	0	0	0	365	70
2	39	200	1600	0	2000	0	0	400	0
1	40	230	800	0	0	300	0	300	130
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
1	43	2000	350	0	0	0	0	400	100
1	44	1000	2124	0	2000	160	0	240	200
1	45	2100	1600	1500	3500	140	0	360	60

REGION	FARM	TOTAL CONSUMPTION-CROP PRODUCTION				ACRES			
		GASOLINE(GAL)	DIESEL(GAL)	PROPANE(GAL)	ELECTRICITY(KW-H)	CORN	S BEANS	S GRAIN	HGA
1	46	2400	5500	0	0	60	300	520	0
1	47	2000	0	0	0	149	0	0	40
1	48	450	1239	0	0	88	0	290	85
1	49	1500	1000	0	0	70	0	250	800
1	50	1500	1549	0	0	70	0	590	340
1	51	735	1981	0	3562	0	0	768	671
1	52	1525	625	0	0	0	0	290	90
5	53	1000	4000	0	0	300	0	320	350
5	54	2000	2000	0	0	150	0	200	100
5	55	6500	9800	0	0	70	0	2800	550
5	56	1500	1000	0	0	112	0	50	0
5	57	1127	0	0	0	83	0	101	3
2	58	800	1200	0	0	20	0	280	80
2	59	1375	2770	0	0	60	0	435	100
2	60	1520	1200	0	0	70	0	200	65
2	61	650	1086	0	500	38	0	660	250
2	62	2641	1289	0	2000	18	0	350	100
2	63	400	1250	0	0	25	0	265	65
2	64	3600	5000	0	0	0	0	800	200
2	65	1200	1700	0	0	0	0	670	0
2	66	1000	3000	0	0	80	0	300	200
2	67	492	1278	0	0	50	0	410	75
2	68	1610	8310	1793	3540	96	0	867	62
2	69	1476	530	0	2080	10	0	170	47
2	70	835	2000	0	10000	150	0	600	160
2	71	300	3000	0	4000	90	0	300	110
2	72	1500	3500	0	0	0	0	520	100
2	73	1000	600	0	0	50	0	100	50
2	74	1000	0	0	0	0	0	129	42
2	75	2000	3500	0	0	30	0	600	150
5	76	1500	1788	0	0	0	0	600	1000
5	77	12000	7500	0	0	30	0	160	480
5	78	800	2000	500	0	140	0	300	100
5	79	4800	1200	0	0	120	0	115	1100
5	80	.189	7185	1500	15000	350	0	550	400
4	81	2100	1131	0	0	130	33	52	50
4	82	2800	1150	0	2000	270	160	100	72
4	83	1000	900	0	5000	135	40	80	20
4	84	800	750	0	0	80	11	90	20
4	85	1800	0	0	0	90	35	20	110
4	86	2000	5500	1215	0	125	0	120	45
4	87	550	450	300	0	20	0	110	10
4	88	850	0	0	0	91	34	50	37
4	89	300	2500	0	0	140	0	150	200
4	90	2000	1500	1600	20000	240	0	0	0

REGION	FARM	TOTAL CONSUMPTION-CROP PRODUCTION				ACRES			
		GASOLINE(GAL)	DIESEL(GAL)	PROPANE(GAL)	ELECTRICITY(KW-H)	CORN	S BEANS	S GRAIN	HGA
4	91	2800	700	0	50	130	0	130	50
4	92	1000	800	0	800	95	0	85	0
4	93	4000	0	300	5000	250	50	60	60
4	94	1200	1000	0	0	100	0	100	33
4	95	951	1303	0	0	90	0	40	35
4	96	1014	1103	0	0	107	60	70	85
4	97	444	800	0	0	0	0	120	300
4	98	2200	1400	0	0	280	0	0	80
4	99	4607	2060	3810	5300	400	0	450	70
3	100	3200	3200	1000	1100	225	30	250	155
3	101	200	300	0	0	50	0	50	40
3	102	900	300	2000	0	100	0	85	55
3	103	100	350	0	0	0	0	50	12
3	104	1368	0	0	0	45	0	35	0
3	105	2000	4000	0	310	301	12	290	55
3	106	500	700	0	0	161	0	200	150
3	107	500	1046	0	0	90	0	80	40
3	108	1500	1900	0	0	320	0	60	150
3	109	0	1401	2000	0	180	0	160	50
3	110	150	500	0	0	130	0	100	0
3	111	700	900	0	3000	95	0	78	50
3	112	700	800	500	5000	150	0	150	40
3	113	1200	1526	325	2000	220	0	320	5
3	114	800	350	0	0	25	0	50	60
3	115	400	1500	675	0	165	0	160	50
3	116	400	0	300	1000	42	32	41	0
3	117	1200	0	0	5000	125	60	125	15
3	118	700	200	0	0	100	0	30	50
3	119	1250	500	0	450	44	100	0	0
3	120	2000	8000	0	0	840	0	0	0
3	121	1401	600	0	0	90	0	90	60
3	122	1500	3000	0	10000	200	0	400	50
3	123	30	0	0	0	40	0	37	48
3	124	400	0	0	0	20	0	20	30
2	125	900	0	0	0	40	0	200	70
2	126	2700	600	0	0	93	0	343	154
1	127	2000	0	0	0	40	0	120	300
1	128	5000	3200	3000	45000	210	0	200	100
1	129	1000	0	0	2000	40	0	0	85
1	130	2578	1572	0	0	70	0	350	0
1	131	500	1000	0	0	72	0	245	50
1	132	600	1000	0	0	40	0	440	40
1	133	1600	1200	0	0	75	0	607	0
1	134	200	1060	0	0	40	0	330	80
1	135	2000	0	300	600	0	0	280	0
1	136	1500	5700	0	9500	0	0	1800	0
1	137	2000	6230	4400	30102	105	0	950	150
1	138	2600	9880	3640	0	215	0	1250	170

REGION	FARM	NITROGEN LB/ACRE				PHOSPHORIC ACID LB/ACRE				POTASH LB/ACRE				CHEMICALS LB/ACRE			
		CORN	S BEANS	S GRAIN	H&A	CORN	S BEANS	S GRAIN	H&A	CORN	S BEANS	S GRAIN	H&A	CORN	S BEANS	S GRAIN	H&A
4	1	0	0	60	0	0	0	37	0	0	0	18	0	0	0	0	0
4	2	30	0	35	0	20	0	20	0	10	0	10	0	0	0	0	0
4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	100	0	0	0	50	0	0	0	20	0	0	0	0	0	0	0
4	5	25	0	20	0	0	0	20	0	0	0	0	0	0	30	0	0
4	6	80	0	40	0	40	0	20	50	20	0	10	5	7	0	0	0
4	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	8	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	9	100	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0
4	10	3	0	25	25	4	0	25	25	2	0	10	10	2	5	0	0
4	11	0	0	43	0	0	0	43	0	0	0	0	0	2	0	1	0
4	12	40	0	33	46	30	0	25	44	15	0	18	0	0	0	0	0
4	130	0	0	35	18	0	0	35	35	0	0	0	0	7	0	0	0
4	140	116	0	39	6	34	0	20	34	0	0	9	16	13	0	0	0
4	15	30	0	30	20	30	0	30	60	15	0	15	16	13	0	1	0
4	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
4	18	0	0	25	0	0	0	12	0	0	0	8	0	8	0	0	0
4	19	30	30	30	30	30	30	30	30	9	9	9	9	0	0	0	0
3	20	0	0	50	0	0	0	20	0	0	0	5	0	5	0	0	0
3	21	42	0	33	0	33	0	33	0	14	0	14	0	17	0	1	0
3	22	50	0	35	0	20	0	35	0	0	0	0	0	15	0	0	0
3	23	0	0	0	0	0	0	0	0	0	0	0	0	7	0	8	0
3	24	100	0	35	0	0	0	45	0	0	0	10	0	1	0	1	0
3	25	80	0	40	0	40	0	20	40	20	0	10	20	12	5	0	0
3	26	75	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
2	27	0	0	9	0	0	0	23	0	0	0	0	0	1	0	1	0
2	28	35	0	41	0	15	0	46	0	0	0	0	0	1	0	1	0
2	29	0	0	7	0	0	0	7	0	0	0	4	0	0	0	0	0
2	30	0	0	18	0	0	0	18	0	0	0	0	0	0	0	1	0
2	31	150	0	9	20	36	0	18	0	0	0	0	0	0	0	0	0
2	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	33	29	0	18	18	29	0	46	46	0	0	0	0	1	0	1	0
2	34	100	0	0	0	50	0	0	0	0	0	0	0	0	0	1	0
2	35	30	0	15	0	30	0	15	0	0	0	0	0	1	0	0	0
2	36	50	0	40	0	26	0	40	0	0	0	0	0	0	0	0	0
2	37	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
2	38	0	0	26	28	0	0	0	0	0	0	0	0	0	0	0	0
2	39	0	0	25	0	0	0	25	0	0	0	0	0	0	0	0	0
1	40	35	0	55	0	14	0	20	0	0	0	0	0	8	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	44	130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	45	0	0	35	0	0	0	0	0	0	0	0	0	9	0	0	0

REGION	FARM	NITROGEN LB/ACRE				PHOSPHORICACID LB/ACRE				POTASH LB/ACRE				CHEMICALS LB/ACRE			
		CORN	S BEANS	S GRAIN	HGA	CORN	S BEANS	S GRAIN	HGA	CORN	S BEANS	S GRAIN	HGA	CORN	S BEANS	S GRAIN	HGA
1	4E	1CC	0	42	0	30	0	22	0	0	0	0	0	8	2	2	C
1	47	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	C
1	4E	C	0	0	0	C	0	0	0	0	0	0	0	0	0	0	0
1	45	C	0	0	0	0	0	0	0	0	0	0	0	16	0	1	0
1	5C	C	0	C	0	0	0	0	0	0	C	0	0	0	0	0	0
1	51	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	C
1	52	C	C	C	0	C	0	0	0	0	0	0	0	0	0	0	C
5	53	C	C	C	0	0	0	0	0	0	0	0	0	1	0	1	C
5	54	C	0	C	0	C	0	0	0	0	0	0	0	0	0	0	C
5	55	150	0	34	0	0	0	10	0	0	0	0	0	4	0	1	C
5	5E	1CC	C	4C	C	0	0	0	0	0	0	0	0	0	0	0	C
5	57	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	58	28	0	2E	0	28	0	28	0	0	0	0	0	0	0	0	C
2	55	11C	0	1E	10	2C	0	32	40	16	0	8	20	4	0	C	C
2	6C	35	0	20	0	21	0	20	48	10	0	1C	0	0	0	0	C
2	61	EC	0	34	22	40	0	56	80	0	0	0	C	0	0	0	C
2	62	C	0	50	0	0	0	30	0	0	0	20	0	0	0	0	0
2	63	C	0	C	0	0	0	0	0	0	0	0	0	0	0	0	0
2	64	C	0	2C	20	0	0	20	20	0	0	0	0	0	0	1	C
2	65	C	0	13	C	C	0	20	0	0	0	0	0	0	0	1	0
2	6E	50	0	5C	0	4C	0	0	0	10	0	10	0	1	0	1	C
2	67	40	0	24	0	2C	0	44	0	0	0	0	0	0	0	5	C
2	6E	166	0	75	0	64	0	10	0	30	0	0	C	0	70	0	C
2	65	0	0	40	0	C	0	20	0	0	0	40	0	0	0	1	0
2	7C	3C	0	2C	0	25	0	20	0	0	0	0	0	8	C	1	C
2	71	C	C	C	0	0	0	0	0	0	0	0	0	8	0	1	C
2	72	C	0	7	0	C	0	9	0	0	0	0	0	0	0	1	C
2	73	20	0	0	0	0	0	0	0	0	0	0	20	1	0	1	C
2	74	C	C	C	0	C	0	0	0	0	0	0	0	0	0	1	C
2	75	5C	0	50	C	5C	0	50	0	0	0	0	0	0	0	1	0
5	76	0	0	C	0	C	0	20	20	0	0	0	0	0	0	0	0
5	77	4C	0	4C	0	0	0	0	0	0	0	0	0	0	0	0	C
5	7E	C	C	5C	0	0	0	20	0	0	0	10	0	0	0	0	0
5	75	6C	0	3C	0	0	0	0	0	0	0	0	0	0	0	0	0
5	8C	50	0	50	0	100	0	50	0	0	0	0	0	0	0	0	0
4	81	5C	0	4C	10	4C	0	40	50	20	0	10	0	1	1	0	0
4	82	EC	5	30	0	40	30	25	44	10	30	10	C	1	1	1	1
4	83	C	0	C	0	C	0	0	0	0	0	0	0	5	5	0	0
4	84	65	0	55	0	30	0	35	60	5	0	1C	40	7	7	0	C
4	85	C	0	C	0	0	0	0	0	0	0	0	0	0	0	0	0
4	86	25	0	25	C	20	0	20	0	10	0	10	0	6	0	1	C
4	87	0	0	C	0	0	0	0	0	0	0	0	0	0	0	0	0
4	EE	0	0	6C	0	C	0	30	0	0	0	10	0	0	0	0	C
4	85	15C	0	0	0	10C	0	0	0	100	0	0	0	0	0	0	C
4	9C	100	0	C	C	40	0	0	0	20	0	0	0	0	0	0	0

REGION	FARM	NITROGEN LB/ACRE				PHOSPHORICACID LB/ACRE				POTASH LB/ACRE				CHEMICALS LB/ACRE			
		CORN	S BEANS	S GRAIN	HGA	CORN	S BEANS	S GRAIN	HGA	CORN	S BEANS	S GRAIN	HGA	CORN	S BEANS	S GRAIN	HGA
4	91	0	0	50	100	0	0	25	0	0	0	25	0	10	0	0	0
4	92	5	0	20	0	18	0	10	0	9	0	5	0	5	0	1	0
4	93	50	0	35	0	0	0	10	0	0	0	10	0	2	0	0	0
4	94	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
4	95	22	0	50	0	22	0	38	114	0	0	12	0	3	0	0	0
4	96	0	0	50	0	0	0	0	0	0	0	0	0	9	2	0	0
4	97	0	0	50	50	0	0	0	0	0	0	0	0	0	0	0	0
4	98	0	0	0	18	0	0	0	40	0	0	0	0	0	0	0	0
4	99	0	0	42	0	0	0	25	0	0	0	7	0	7	0	0	0
3	100	50	0	30	0	30	0	20	0	0	0	0	0	0	0	0	0
3	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	103	0	0	35	30	0	0	17	15	0	0	0	0	0	0	0	0
3	104	70	0	60	0	60	0	40	0	20	0	0	0	0	0	0	0
3	105	45	45	45	0	20	20	38	75	15	15	15	0	0	0	0	0
3	106	0	0	0	0	0	0	0	0	0	0	0	0	10	0	5	0
3	107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	109	50	0	50	0	50	0	50	100	0	0	0	0	8	0	1	0
3	110	0	0	25	0	0	0	19	0	0	0	9	0	12	0	1	0
3	111	10	0	25	9	24	0	25	23	0	0	0	0	12	0	0	0
3	112	100	0	75	0	20	0	10	0	10	0	5	0	0	0	1	0
3	113	45	0	18	0	16	0	18	0	6	0	0	0	0	0	0	0
3	114	60	0	40	40	70	0	50	50	20	0	0	0	9	0	1	0
3	115	0	0	45	0	25	0	20	0	25	0	20	0	0	0	0	0
3	116	100	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0
3	117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	118	50	0	0	0	20	0	0	0	10	0	0	0	0	0	0	0
3	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	120	75	0	0	0	40	0	0	0	30	0	0	0	10	0	0	0
3	121	0	0	50	0	0	0	40	0	0	0	0	0	0	0	0	0
3	122	62	0	16	30	0	0	13	21	0	0	0	0	0	0	0	0
3	123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	124	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	125	100	0	50	0	40	0	40	0	0	0	0	0	0	0	0	0
2	126	100	0	50	0	40	0	40	0	0	0	0	0	0	0	0	0
1	127	120	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0
1	128	100	0	50	0	62	0	25	0	38	0	15	0	10	0	0	0
1	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	130	20	0	20	0	10	0	10	0	0	0	0	0	0	0	1	0
1	131	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0
1	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	133	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	134	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
1	136	0	0	20	0	0	0	10	0	0	0	0	0	0	0	1	0
1	137	30	0	30	0	0	0	0	0	0	0	0	0	7	0	1	0
1	138	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX C

Appendix Table C_1: Analysis of Variance for Eastern South Dakota Corn Production By Region, (1978).

Source	Dependent Variable - Acres of Corn DF	MS	F
Regions	4	76670.43	6.83*
Error	131	11217.38	
Corrected Total	135		

* Highly significant

Appendix Table C_2: Analysis of Variance for Eastern South Dakota Soybean Production By Region, (1978).

Source	Dependent Variable - Acres of Soybeans DF	MS	F
Regions	4	3363.54	2.50**
Error	131	1346.19	
Corrected Total	135		

** Significant

Appendix Table C_3: Analysis of Variance for Eastern South Dakota Small Grain Production By Region, (1978).

Source	Dependent Variable - Acres of Small Grains DF	MS	F
Regions	4	935317.36	10.52*
Error	131	88902.40	
Corrected Total	135		

* Highly Significant

Appendix Table C_4: Analysis of Variance for Eastern South Dakota Hay and Alfalfa Production By Region, (1978).

Source	Dependent Variable - Acres of Hay and Alfalfa DF	MS	F
Regions	4	290197.66	14.17*
Error	131	20482.42	
Corrected Total	135		

* Highly significant

APPENDIX D

Appendix Table D_1: Analysis of Variance for Eastern South Dakota Gasoline Consumption/Acre By Region, (1978).

Source	Dependent Variable - Gasoline/Acre DF	MS	F
Regions	4	29.20	3.10**
Error	129	9.43	
Corrected Total	133		

** Significant

Appendix Table D_2: Analysis of Variance for Eastern South Dakota Diesel Fuel Consumption/Acre By Region, (1978).

Source	Dependent Variable - Diesel/Acre DF	MS	F
Regions	4	5.57	0.97^{NS}
Error	110	5.75	
Corrected Total	114		

^{NS} Not Significant

Appendix Table D_3: Analysis of Variance for Eastern South Dakota Liquid Propane Gas Consumption/Acre By Region, (1978).

Source	Dependent Variable - Propane/Acre DF	MS	F
Regions	4	3.03	0.69^{NS}
Error	21	4.39	
Corrected Total	25		

^{NS} Not significant

Appendix Table D_4: Analysis of Variance for Eastern South Dakota Electricity Consumption/Acre By Region, (1978).

Source	Dependent Variable - Electricity/Acre DF	MS	F
Regions	4	520.44	0.87^{NS}
Error	45	595.28	
Corrected Total	49		

^{NS} Not Significant

APPENDIX E

Appendix Table E_1: Analyses of Variance for Eastern South Dakota Fertilizer Consumption/Acre For Corn Production By Region, (1978).

Source	DF	MS (N)	MS (P_2O_5)	MS (K_2O)	F Value
	Dependent Variables - Nitrogen (N), Phosphorus acid (P_2O_5), Potash (K_2O)				
Regions	4	1237.64	797.45	162.65	N - 0.65^{NS}
Error	114	1901.78	446.03	137.11	P_2O_5 - 1.79^{NS}
Corrected Total	118				K_2O - 1.19^{NS}

NS Not Significant

Appendix Table E_2: Analyses of Variance for Eastern South Dakota Fertilizer Consumption/Acre For Soybean Production By Region, (1978).

Source	DF	MS (N)	MS (P_2O_5)	MS (K_2O)	F Value
	Dependent Variables - Nitrogen (N), Phosphorus acid (P_2O_5), Potash (K_2O)				
Regions	2	71.45	5.88	2.74	N - 0.59^{NS}
Error	21	120.97	91.50	51.38	P_2O_5 - 0.06^{NS}
Corrected Total	23				K_2O - 0.05^{NS}

NS Not Significant

Appendix Table E_3: Analyses of Variance for Eastern South Dakota Fertilizer Consumption/Acre For Small Grain Production By Region, (1978).

Source	Dependent Variables - Nitrogen (N), Phosphorus acid (P_2O_5), Potash (K_2O)				
	DF	MS (N)	MS (P_2O_5)	MS (K_2O)	F Value
Regions	4	518.90	987.53	146.87	N - 1.20^{NS}
Error	121	432.39	235.19	37.97	P_2O_5 - 4.20*
Corrected Total	125				K_2O - 3.87*

* Highly significant

^{NS} Not significant

Appendix Table E_4: Analyses of Variance for Eastern South Dakota Fertilizer Consumption/Acre For Hay Production By Region, (1978).

Source	Dependent Variables - Nitrogen (N), Phosphorus Acid (P_2O_5), Potash (K_2O)				
	DF	MS (N)	MS (P_2O_5)	MS (K_2O)	F Value
Regions	4	333.68	1074.92	31.16	N - 1.93^{NS}
Error	112	173.02	471.73	28.44	P_2O_5 - 2.28^{NS}
Corrected Total	116				K_2O - 1.10^{NS}

^{NS} Not significant

APPENDIX F

Appendix Table F_1: Analysis of Variance for Eastern South Dakota Chemical Consumption/Acre For Corn Production By Region, (1978).

Dependent Variable - Chemicals Consumption For Corn Production			
Source	DF	MS	F Value
Regions	4	55.62	2.80^{NS}
Error	112	19.84	
Corrected Total	116		

NS Not significant

Appendix Table F_2: Analysis of Variance for Eastern South Dakota Chemical Consumption/Acre For Soybean Production By Region, (1978).

Dependent Variable - Chemical Consumption For Soybean Production			
Source	DF	MS	F Value
Regions	3	16.44	0.43^{NS}
Error	23	38.14	
Corrected Total	26		

NS Not significant

Appendix Table F_3: Analysis of Variance For Eastern South Dakota Chemical Consumption/Acre For Small Grain Production, By Region (1978).

Dependent Variable - Chemical Consumption For Small Grain Production			
Source	DF	MS	F Value
Regions	4	1.21	1.15^{NS}
Error	120	1.05	
Corrected Total	124		

^{NS} Not significant

Appendix Table F_4: Analysis of Variance for Eastern South Dakota Chemical Consumption/Acre For Hay Production By Region, (1978).

Dependent Variable - Chemical Consumption For Hay Production			
Source	DF	MS	F Value
Regions	4	0.005	0.58^{NS}
Error	112	0.009	
Corrected Total	116		

^{NS} Not significant

APPENDIX G

Appendix Table G: Analysis of Variance for Eastern South Dakota Energy Consumption/Acre (Fertilizers and Chemicals) By Crop and Region, (1978).

	Dependent Variable - Mean Consumption of Fertilizers and Chemicals (kcal/Acre)		
Source	DF	MS	F Value
Model	7	8982.70×10^8	15.37*
Error	382	584.38×10^8	
Corrected Total	389		
Regions	4	773.07×10^8	1.32^{NS}
Crops	3	20213.28×10^8	34.59*

* Highly significant

^{NS} Not significant

APPENDIX H

Appendix Table H: Analysis of Variance for Eastern South Dakota Energy Consumption/Acre (Gasoline, Diesel Fuel, Liquid Propane Gas and Electricity) By Region, (1978).

Dependent Variable - Summation of Gasoline, Diesel Fuel, Propane Gas and Electricity (kcal/Acre)			
Source	DF	MS	F
Regions	4	519.73×10^8	2.71**
Error	131	192.00×10^8	
Corrected Total	135		

** Significant

APPENDIX I

Appendix Table I: Analysis of Variance for Eastern South Dakota Total Energy Consumption/Acre By Region, (1978).

Dependent Variable - Summation of Gasoline, Diesel Fuel, Propane Gas, Electricity, Fertilizers and Chemicals, (kcal/Acre)			
Source	DF	MS	F
Regions	4	5913.56×10^8	1.93^{NS}
Error	131	3062.51×10^8	
Corrected Total	135		

NS Not significant